

## Morphology and Ecological Notes on the Larvae and Pupae of *Simulium* (*Simulium*) from Korea

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### ABSTRACT

Morphological features of larvae and pupae of twelve species of *Simulium* (*Simulium*) from Korea are investigated and redescribed. Detailed descriptions of immature stages of each species are provided with photographs. For the Korean members of subgenus *Simulium*, combinations of the following characteristics can be used to separate them from other Korean subgenera: larval abdomen without a pair of conical-shaped ventral tubercles; postgenal cleft variously shaped, viz., miter shaped, spearhead, bullet shaped or triangular; rectal papillae 3 simple lobe or compound lobes; pupal gill of 6–16 filaments; cocoon shoe, boot or slipper shaped; and head trichomes 3 pairs (1 facial + 2 frontal). Habitat information and other ecological aspects of each species are provided. Updated keys to larvae and pupae of the Korean species of the subgenus *Simulium* are also provided to facilitate species identification. Taxonomic treatment based on external morphologies of larvae and pupae of Korean species of the subgenus *Simulium* are focused and included in this study. To understand their interspecific relationships, phylogenetic analyses using multiple data from molecule, morphology, and ecology are warranted in future research. Also continued exploration for new character systems is needed to establish more stable boundaries for subgenus and species delimitations.

**Key words** : aquatic insect, black fly, key, Korean Simuliidae, taxonomy

### INTRODUCTION

Black flies (Diptera: Simuliidae) are small insects and many species are known as notorious pests of human and domestic animals medically and veterinarianly in many parts of the world (Adler et al., 2004). Currently, twenty-one species of black flies are known to be distributed in Korea (Adler and Crosskey, 2015). Almost all of them belong to the genus *Simulium* Latreille, except single species, *Helodon* (*Helodon*) *multicaulis*, further placed into 4 subgenera, i.e., *Gomphostilbia* (2 spp.), *Nevermannia* (5 spp.), *Simulium* (12 spp.), and *Wilhelmia* (1 sp.).

Bentinck (1955) reported 28 species of black flies from Japan and Korea among which 17 species are recorded from Korea. Yoon and Song (1989, 1990) was the first who taxonomically reviewed 15 Korean black flies in subgenera *Gomphostilbia*, *Nevermannia*, and *Simulium*. Recently, Kim (2015b) provided updated keys and revised descriptions of 7 species of the subgenera *Gomphostilbia* and *Nevermannia*. The subgenus *Simulium* is the largest subgenera in the genus

*Simulium*, with over 520 recorded species in 25 species-group from the world (Adler and Crosskey, 2015). Presence of prominent ventral tubercles on larval abdomen can be used to separate members of subgenera *Gomphostilbia* and *Nevermannia* from the members of subgenus *Simulium* (Takaoka, 1977b). Because members of subgenus *Simulium* are varied greatly morphologically, no clearly defined diagnostic characters for the subgenus is available. In this article morphological features of larvae and pupae of twelve species of Korean *Simulium* (*Simulium*) were examined and redescriptions were provided with accompanying photographs. This will contribute to draw the boundary of loosely defined subgenus, at least for Korean species. Ecological aspects including habitats, biting habit, seasonality, and natural enemies also provided to broaden our knowledge on the little known flies. Updated keys to larvae and pupae of the Korean species of the subgenus *Simulium* are also provided to facilitate species identification within the subgenus. Taxonomic treatment based on external morphologies of larvae and pupae of Korean species of the subgenus *Sim-*

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*ulium* are focused and included in this study. To understand their interspecific relationships, phylogenetic analyses using multiple data from molecule, morphology, and ecology are warranted in future research. Also continued exploration for new character systems is needed to establish more stable boundaries for subgenus and species delimitations.

## MATERIALS AND METHODS

Larvae and pupae of Korean black flies were collected from various streams with fine forceps and placed in vials containing either 95% ethanol (for molecular analyses) or Carnoy's fixative (for chromosome analyses). Fixatives were replenished immediately after collection with fresh ones and once again within a few hours of collection for best fixation. Fixed larvae and pupae were kept in freezer ( $-8^{\circ}\text{C}$ ) until examinations. External features of larvae and pupae were examined by using dissecting microscope (Leica M165C; Leica, Wetzlar, Germany) and macroscope (Leica Z16 APO; Leica). Head region of ultimate instar larvae was removed from the body by using two sets of fine forceps and were placed in a vial containing 10% KOH and boiled for 10 min. at about  $70^{\circ}\text{C}$  to facilitate examination of larval hypostoma with phase-contrast microscopy. Cleared heads then were placed in a vial containing 3% acetic EtOH for 30 s. to neutralized them. Larval hypostoma were carefully recovered from the cleared heads by using fine forceps and minuten needles. Hooks of posterior proleg were also recovered from the larvae by teasing the end of the abdomens with minuten needles. Recovered hypostoma and hooks of posterior prolegs were placed in a drop of glycerin on a microscope slide and a cover slip was applied. Then clear finger nail polish was applied to seal the preparations. The preparations were examined and measured with phase-contrast microscopy (Leica DM 2500). Photographs were taken with a CCD digital camera (Leica DFC 295; Leica) attached to the microscopes.

Digital images of larvae and pupae of black flies were taken with a CCD digital camera, accompanied with Z-builder and analytical software (Leica Application Suite; Leica) to measure the length and width of each specimen. To obtain high quality digital images, consecutive digital images in different focal planes were taken with a Sony NEX-7 digital camera (Sony, Tokyo, Japan) attached to the microscope and the images were Z-stacked by using Helicon Focus software (Helicon Soft Ltd., Kharkov, Ukraine).

The specimens used in this study are deposited in the Department of Applied Biology, Kangwon National University, Chuncheon-si, Korea.

## SYSTEMATIC ACCOUNTS

Order Diptera Linnaeus, 1758

Family Simuliidae Latreille, 1802

Genus *Simulium* Latreille, 1802

*Simulium* Latreille, 1802: 426 (as genus), type species: *Oestrus columbacensis* Scopoli by monotypy.

Subgenus *Simulium* Enderlein, 1921

**Diagnosis.** For Korean members of subgenus *Simulium*, combination of the following characteristic can be used to separate them from members of other Korean subgenera: larval abdomen without a pair of conical-shaped ventral tubercles, postgenal cleft miter shaped, spearhead shaped or triangular, rectal papillae 3 simple lobe or compound lobes; pupal gill of 6–16 filaments, cocoon shoe or slipper shaped, head trichomes 3 pairs (1 facial + 2 frontal).

**Remarks.** The subgenus *Simulium* is the largest in the family, with over 520 recorded species in 25 species-group from the world (Adler and Crosskey, 2015). Twelve species are assigned in 9 species-group in Korea. Biting habits of females of many species are not well understood (Bentinck, 1955) but some are known to bite human and other mammals and are known as natural vectors of *Onchocerca* spp., causative agent of zoonotic onchocerciasis in wild boar (*Sus scrofa*), cow (*Bos taurus*), and sika deer (*Cervus nippon*) in Japan (Takaoka et al., 2012). Nothing is known about the role of black flies in transmitting diseases in wild animals and human in Korea. Also little is known about the ecological aspects of each species such as distribution pattern, seasonality, voltinism, and natural enemies.

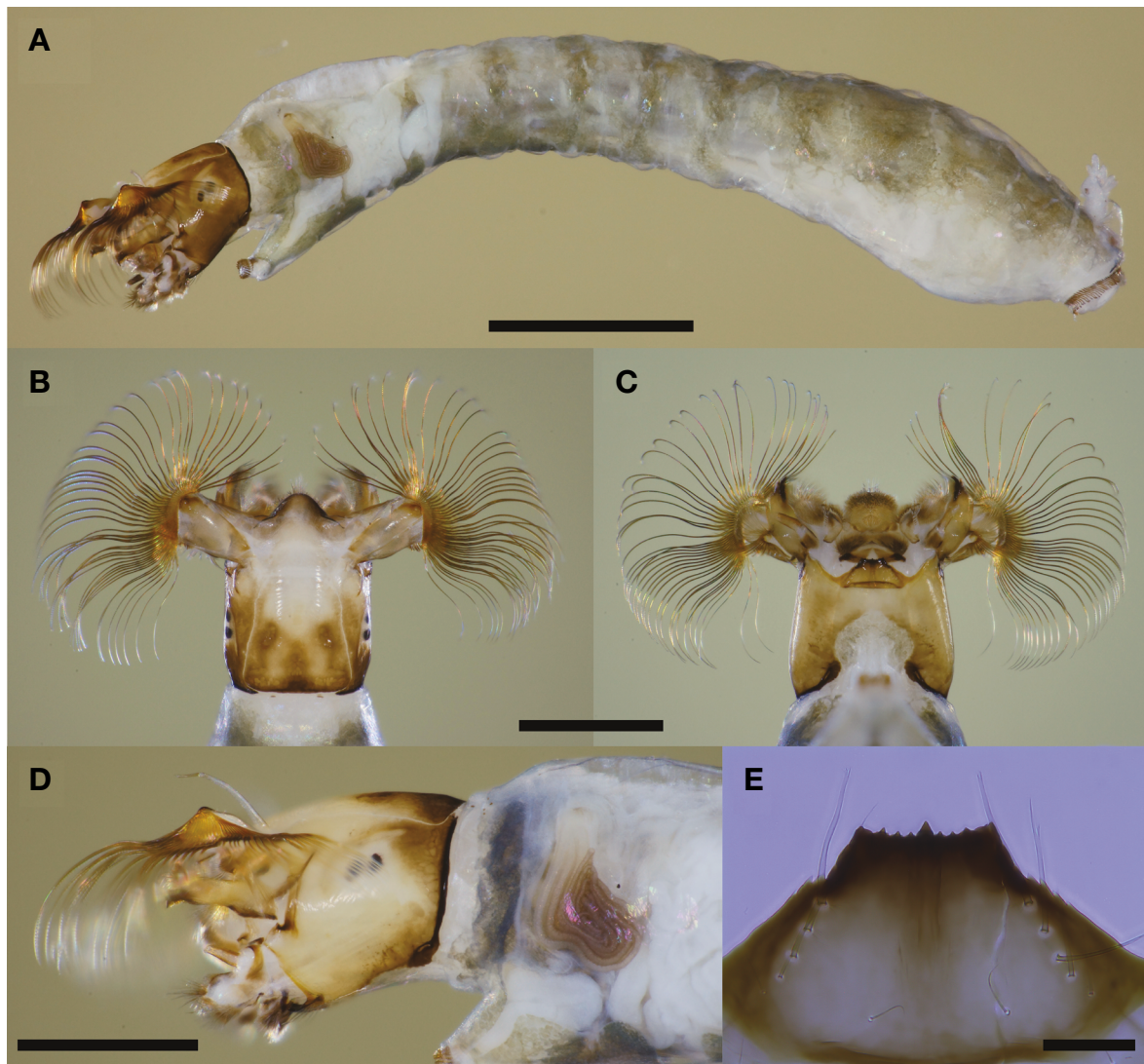
### Keys to larvae and pupae of Korean species of *Simulium* (*Simulium*)

#### Larvae

1. Postgenal cleft shallow, as long as postgenal bridge (Fig. 18C) ..... *Simulium iwatanse*  
Postgenal cleft deep, much longer than postgenal bridge ..... 2
2. Postgenal cleft miter shaped, as long as wide (Fig. 1C) ..... 3  
Postgenal cleft other than miter shaped, as long as or longer than wide ..... 8
3. Postgenal cleft almost reaching to hypostomal groove; gill histoblast with 16 filaments (Fig. 12C) ..... *Simulium malyschevi*  
Postgenal cleft not reaching to hypostomal groove; gill histoblast with less than 16 filaments ..... 4



4. Each abdominal segments with a pair of dorsal protuberances; abdominal cuticle covered with minute dark setae (Fig. 21A) ..... *Simulium quinquestriatum*  
Each abdominal segments without a pair of dorsal protuberances; abdominal cuticle without minute dark setae ..... 5
  5. Area surrounding head spots darkly pigmented, hat-shaped (Figs. 4B, 6B) ..... 6  
Area surrounding head spots not darkly pigmented (Figs. 1B, 15B) ..... 7
  6. Rectal papillae 3 simple lobes (Fig. 5C) ..... *Simulium coreanum*  
Rectal papillae 3 lobes, each with 5–7 secondary lobules (Fig. 7C) ..... *Simulium nikkoense*
  7. Postgenal cleft darkly pigmented; gill histoblast with 8 filaments (Fig. 1C, D) ..... *Simulium bidentatum*  
Postgenal cleft not darkly pigmented; gill histoblast with 6 filaments (Figs. 15C, 16A) ..... *Simulium nacojapi*
  8. Postgenal cleft triangular; head capsule dark brown (Fig. 9C) ..... *Simulium japonicum*  
Postgenal cleft not triangular; head capsule various colored ..... 9
  9. Head spot negative, H-form (Fig. 33B) ..... *Simulium arakawae*  
Head spot positive, if negative, not H-form ..... 10
  10. Head spot distinctive positive; subesophageal ganglion darkly pigmented (Fig. 30B, C) ..... *Simulium oitanum*  
Head spot positive or negative, not distinctive; subesophageal ganglion not darkly pigmented ..... 11
  11. Abdominal segments with banding patterns; all head spots positive (Fig. 27A, B) ..... *Simulium suzukii*  
Abdominal segments without banding patterns; head with anterolateral and posterolateral spots negative (Fig. 24A, B) ..... *Simulium rufibasis*
- Pupae (except *Simulium coreanum*)
1. Cocoon shoe or boot shaped (Figs. 3A, 11A) ..... 2  
Cocoon slipper shaped (Fig. 26A) ..... 5
  2. Cocoon shoe shaped; gill of 6 filaments (Fig. 11A) ..... *Simulium japonicum*  
Cocoon boot shaped; gill of 8 or more filaments ..... 3
  3. Gill of 8 filaments (Fig. 3B) ..... *Simulium bidentatum*  
Gill of 10 or more filaments ..... 4
  4. Gill of 10 filaments (Fig. 23B) ..... *Simulium quinquestriatum*  
Gill of 16 filaments (Fig. 14A, B) ..... *Simulium malyschevi*
  5. Cocoon anteriorly with lateral aperture ..... *Simulium nacojapi*  
Cocoon without lateral aperture ..... 6
  6. Gill of 8 filaments ..... 7
- Gill of 6 filaments ..... 8
  7. Gill with (1 + 1 + 1) + 1 + (2 + 2) arrangement (Fig. 8B); abdominal tergite 6 with spine comb (Fig. 8D) ..... *Simulium nikkoense*  
Gill with 2 + 2 + 2 + 2 arrangement (Fig. 20B); abdominal tergite 6 without spine comb (Fig. 20D) ..... *Simulium iwataense*
  8. Gill with dorsalmost pair of filaments directed upwardly than forwardly, perpendicularly arranged; angle between dorsalmost filament and ventralmost filament well over 100° (Fig. 32B) ..... 9  
Gill with dorsalmost pair of filaments directed diagonally than forwardly; angle between dorsalmost filament and ventralmost filament about or less than 90° (Fig. 26A) ..... 10
  9. Gill with stalk of dorsalmost pair as long as other stalks (Fig. 32C); abdominal tergite 6 with weakly developed spine comb (Fig. 32E) ..... *Simulium oitanum*  
Gill with stalk of dorsalmost pair longer than other stalks (Fig. 35B); abdominal tergite 6 with well-developed spine comb (Fig. 35D) ..... *Simulium arakawae*
  10. Head with frontal trichome long (Fig. 26C); terminal hooks not developed (Fig. 26D); stalk of all gill filaments equal in length ..... *Simulium rufibasis*  
Head with frontal trichome short, indistinctive (Fig. 29B, C); terminal hooks moderately developed (Fig. 29D); ventral stalk of gill filaments longer than others ..... *Simulium suzukii*
- Argentipes species-group**
- Argentipes* species-group contains 6 species which are all recorded from Oriental and Palaearctic region (Adler and Crosskey, 2015). Single species is known to occur in Korea.
- Simulium (Simulium) bidentatum* (Shiraki, 1935) (Figs. 1–3)**
- Odagmia bidentata* Shiraki, 1935: 34 (type locality: Jifuku, Yamaguchi prefecture, Japan); Takahasi, 1950: 1557 (taxonomy).
- Simulium (Odagmia) bidentatum*: Ogata and Sasa, 1954: 331 (Japanese list); 1955a: 10–18 (Japanese key); Ogata and Sasa, 1955b: 40 (Japanese list); Ogata et al., 1956: 84 (taxonomy and ecology); Shogaki, 1956: 275 (Japanese list and taxonomy); Anonymus, 1965: 191 (redescription in Japanese); Orii et al., 1969: 1–13 (Japanese key); Uemoto, 1985: 331 (Japanese key and taxonomy); 2005: 1018 (Japanese key and taxonomy); Moncada et al., 1987: 26 (ecology).
- Simulium bidentatum*: Bentinck, 1955: 11 (Korean and Japanese species and key); Chow, 1973: 44 (Korean list); Takahasi and Saito, 1974: 274 (ecology); Takaoka, 1982:



**Fig. 1.** *Simulium (Simulium) bidentatum*. A, Larva, lateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars=1 mm (A), 0.5 mm (B–D), 50  $\mu$ m (E).

151 (ecology); Saito et al., 1985: 244 (ecology); Yamashita et al., 2000: 33 (ecology); Fukuda et al., 2010: 39 (ecology); Paek et al., 2010: 221 (Korean list); Takaoka et al., 2012: 374 (ecology).

*Gnus bidentatum*: Rubtsov, 1962: 441 (taxonomy); Rubtsov and Yankovsky, 1988: 161 (Palearctic catalogue).

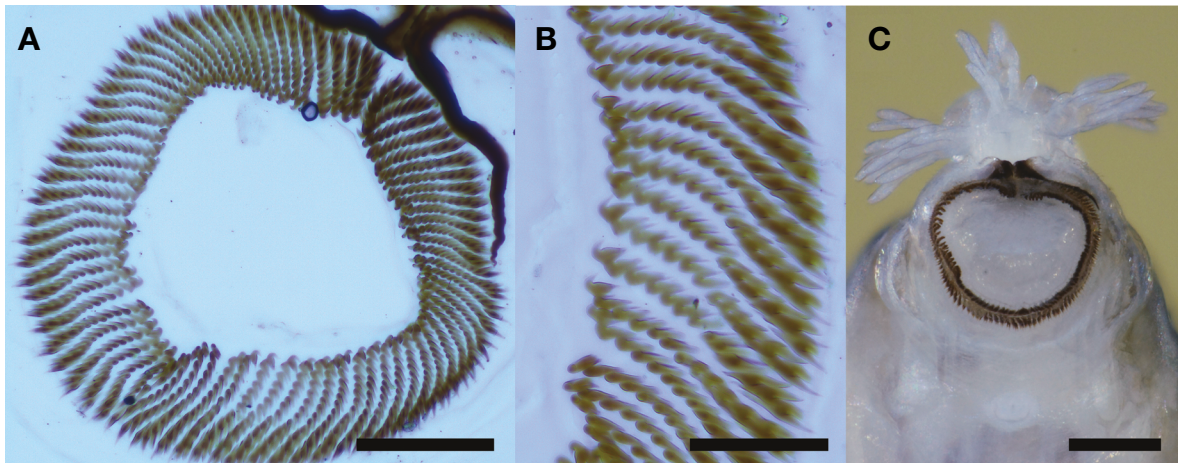
*Simulium (Gnus) bidentatum*: Anonymous, 1974: 192 (Japanese list); Takaoka, 1976: 393 (redescription); 1977b: 219 (Japanese key); Poinar and Takaoka, 1979: 193 (ecology); Takaoka and Okazawa, 1988: 100 (Japanese list); An, 1989: 185 (Chinese checklist).

*Simulium (Simulium) bidentatum*: Crosskey, 1988: 472 (checklist); Yoon and Song, 1989: 39 (taxonomic note); Cro-

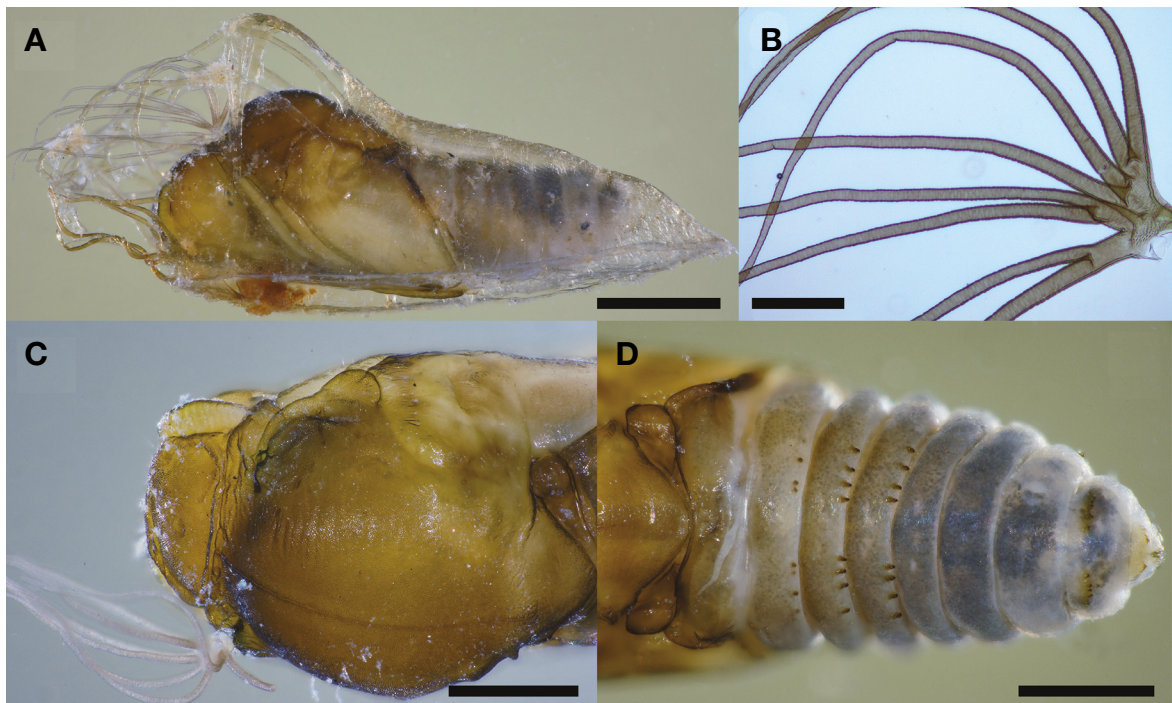
sskey et al., 1996: 424 (Chinese checklist); Takaoka, 2002: 63 (key and ecology); Otsuka et al., 2003: 114 (phylogeny); Crosskey and Howard, 2004: 61 (checklist); Fukuda et al., 2005: 93 (ecology); Kim, 2011a: 202 (redescription); Kim, 2013: 100 (Korean checklist); Adler and Crosskey, 2015: 82 (checklist).

**Material examined.** Korea: Gangwon-do: Chuncheon-si, Seo-myeon, Deokduwon 2-ri, 37°52'07"N, 127°39'12"E, 27 Oct 2009, Kim SK (35 ultimate/penultimate, 75 early instar larvae, 8 pupae); ditto, 29 Oct 2009, Kim SK (45 ultimate/penultimate, 78 early instar larvae, 2 pupae); ditto, Sabukmyeon, Goseong-ri, 38°00'04"N, 127°44'15"E, 30 Oct





**Fig. 2.** *Simulium* (*Simulium*) *bidentatum*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, postero-ventral view. Scale bars=0.1 mm (A), 50  $\mu$ m (B), 0.2 mm (C).



**Fig. 3.** *Simulium* (*Simulium*) *bidentatum*. A, Pupa and cocoon, lateral view; B, Gill filaments, phase-contrast micrograph; C, Pupal head and thorax, dorsolateral view; D, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.2 mm (B), 0.5 mm (C, D).

2009, Kim SK (80 ultimate/penultimate, 64 early instar larvae, 12 pupae); ditto, Sindong-myeon, Jeung-ri, 37°47' 60"N, 127°43'07"E, 6 Nov 2009, Kim SK (94 ultimate/penultimate, 106 early instar larvae, 17 pupae); ditto, Sinbuk-eup, Sancheon-ri, Yulmooncheon stream, 37°56'57"N, 127° 44'56"E, 8 Nov 2009, Kim SK (114 ultimate/penultimate, 53

early instar larvae, 54 pupae); ditto, Seo-myeon, Bangdong-ri, 37°53'45"N, 127°40'49"E, 10 Nov 2009, Kim SK (135 ultimate/penultimate, 75 early instar larvae, 19 pupae); Jeollanam-do: Jangseong-gun, Bukha-myeon, Yongdu-ri, Daeakchen stream, 35°22'57"N, 126°52'09"E, 2 Jun 2012, Kim SK (36 ultimate/penultimate, 108 early instar larvae, 13 pu-

pae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon boot shaped with numerous small apertures at the anterior margin, gill of 8 filaments; and larvae with miter shaped postgenal cleft, positive or seemingly negative head spots, and rectal papillae compound with digit-like long secondary lobules.

**Description.** Mature Larva (Fig. 1). Body length 5.1–6.3 mm ( $n=20$ ). Body (Fig. 1A) greyish yellow to grey. Head capsule (Fig. 1B–D) pale yellow with positive head spots; posterior half of frontoclypeal apotome brown to dark brown, making head spots seemingly negative in some specimens. Antenna (Fig. 1D) pale yellow to yellowish brown, extended beyond apex of labral fan stem by about 1/2 length of distal article. Labral fan (Fig. 1B, C) with 53–58 primary rays. Postgenal cleft (Fig. 1C) miter shaped, widest at midpoint, as long as wide, about  $4\times$  as long as postgenal bridge, mottled with dark spots, lateral elongate spot present, positive. Lateral surface of head capsule (Fig. 1D) without spots under ocelli. Gill histoblast with 8 filaments (Fig. 1D). Hypostoma (Fig. 1E) with 9 apical teeth; median tooth prominent, lateral teeth smaller than median tooth; sublateral teeth small; paralateral teeth not developed; lateral serrations well developed; hypostoma with 4–5 apically branched hypostomal setae. Posterior proleg (Fig. 2A, B) with 14–16 hooks in about 83–85 rows. Rectal papillae (Fig. 2C) of 3 lobes, each with 7–11 digit-like long secondary lobules.

Pupa (Fig. 3). Body length (excluding gill filaments) 2.8–3.5 mm ( $n=20$ ). Cocoon (Fig. 3A) boot shaped with numerous lateral apertures at the anterior margin, embracing gill filaments, 4.1–5.0 mm long. Gill (Fig. 3B) with 8 filaments, about half as long as pupa; base short, giving rise to 4 petiolate pairs of filament, short; in some specimens, dorsalmost pair with long stalk,  $3\times$  as long as wide; second pair from dorsum sessile, arising from base of dorsalmost stalk. Cephalic plates and thorax (Fig. 3C) densely covered with small tubercles. Frons with 2 short, simple trichomes; face with 1 short, simple trichome. Thoracic trichomes in 6 pairs, long and simple, about  $1.3\times$  as long as cephalic trichomes. Abdomen (Fig. 3D) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segments V–VII without spines; segment VIII with row of spine comb; terminal hooks well developed.

**Distribution.** Korea, China, Japan.

**Remarks.** This species is known to feed blood from Japanese deer (*Cervus nippon*), cattle (Bentink, 1955; Yamashita et al., 2000), humans and goats (Ogata and Sasa, 1955a). Immature stages were naturally infected with filarial nematodes (*Onchocerca* sp.) (Takaoka et al., 2012), mermithid nema-

todes (Mermithidae) (Poinar and Takaoka, 1979), and fungi (*Coelomycidium* sp.) (Takaoka, 1982) in Japan and were considered a vector of the causative agent of zoonotic onchocerciasis, *Onchocerca dewittei japonica*, in Japan (Takaoka et al., 2012). Specimens were collected as pupae and larvae from submerged trailing grasses, roots, twigs, leaves, and rocks in the lowland streams totally or partly exposed to sun. A large number of ultimate instar larvae and pupae were collected in November. Many larvae (mostly early instars) were also collected from May to June with low numbers of pupae. About 32% (27 out of 84 specimens) of larvae were infected with unidentified microsporidian fungus from single stream in Korea. The larvae, particularly early instar larvae, were also naturally infected with a cosmopolitan parasitic fungus, *Coelomycidium simulii*.

#### *Noelleri* species-group

*Noelleri* species-group contains 10 species plus 3 cytoforms from the world (Adler and Crosskey, 2015). Two species are known to occur in Korea.

#### *Simulium (Simulium) coreanum* Kim, 2015 (Figs. 4, 5)

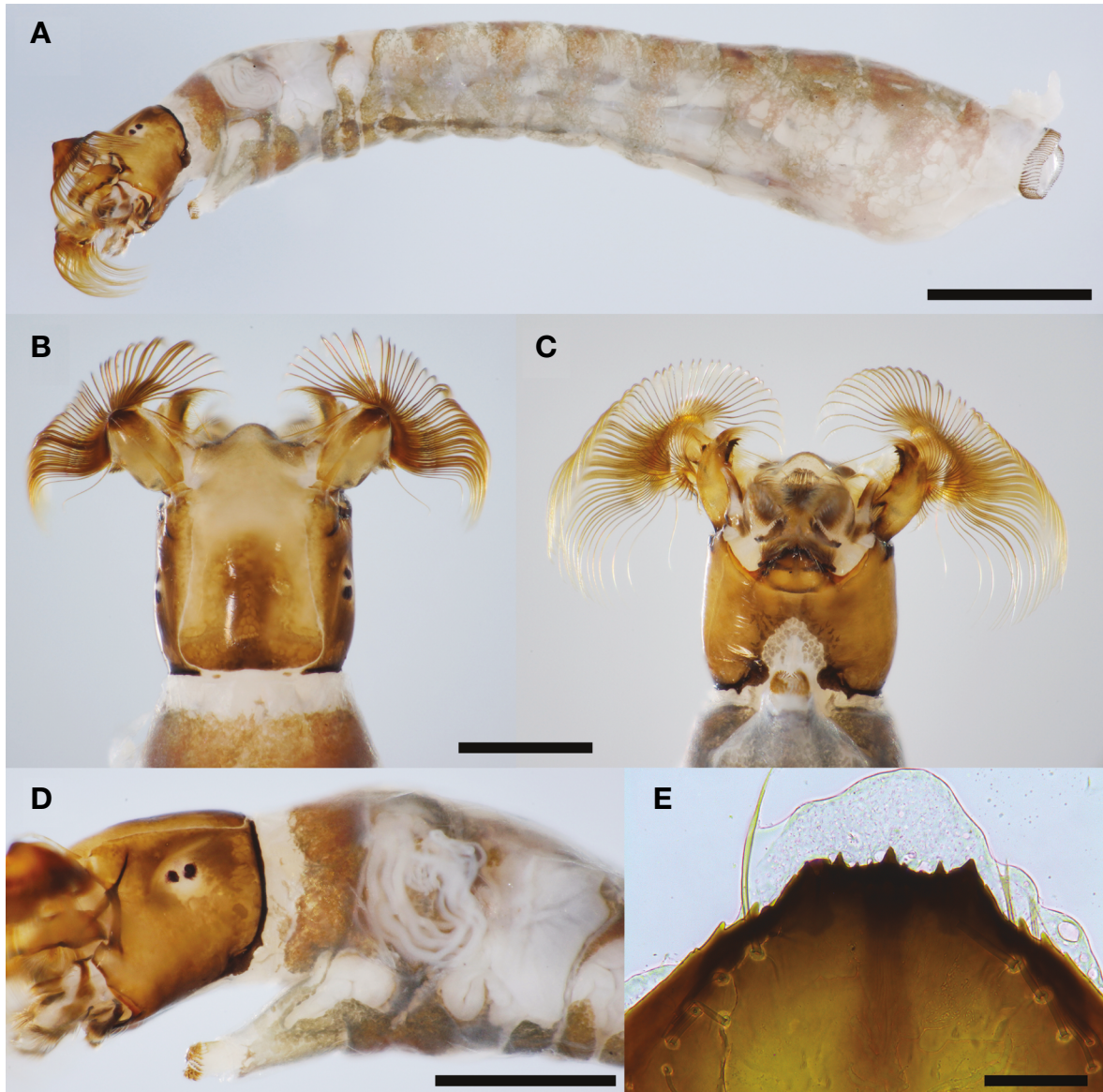
*Simulium (Simulium) coreanum* Kim, 2015a: 31 (type locality: Jeollanam-do, Korea); Adler and Crosskey, 2015: 91 (checklist).

**Material examined.** Korea: Jeollanam-do: Jangseong-gun, Bukha-myeon, Yaksu-ri,  $35^{\circ}26'11''\text{N}$ ,  $126^{\circ}53'01''\text{E}$ , 2 Jun 2012, Kim SK (2 ultimate, 1 penultimate instar larvae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: larval head spot positive but seemingly negative with darkly pigmented surrounding areas, hat shaped, postgenal cleft darkly pigmented, gill histoblast with 8 filaments, and rectal papillae with 3 simple lobes; and pupa unknown.

**Description.** Mature larva (Fig. 4). Body length 6.3–6.7 mm ( $n=3$ ). Body (Fig. 4A) mixture of reddish brown and grey. Head capsule (Fig. 4B–D) yellowish brown ground color with head spot area brown to dark brown; head spot positive but seemingly negative due to dark surrounding areas, hat shaped. Antenna (Fig. 4B) yellowish brown, distal article darker than the rest, as long as labral fan stem. Labral fan (Fig. 4B, C) with 51–59 primary rays. Postgenal cleft (Fig. 4C) miter shaped, not pointed,  $1.2\times$  as long as wide,  $3.3\times$  as long as postgenal bridge, mottled with dark spots, laterally with positive elongate spot. Lateral surface of head capsule (Fig. 4D) with indistinctive negative spot under ocelli. Gill histoblast with 8 filaments (Fig. 4D). Hypostoma (Fig. 4E) with 9 apical teeth; median tooth prominent, lateral teeth smaller than median tooth; sublateral teeth





**Fig. 4.** *Simulium (Simulium) coreanum*. A, Larva, ventrolateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars=1 mm (A), 0.5 mm (B–D), 50 µm (E).

small but tooth adjacent to lateral teeth larger than others; paralateral teeth not developed; lateral serrations well developed; hypostoma with 6 apically branched hypostomal setae. Posterior proleg (Fig. 5A, B) with 12–14 hooks in about 80–82 rows. Rectal papillae (Fig. 5C) of 3 simple lobes.

Pupa. Not available.

**Distribution.** Korea.

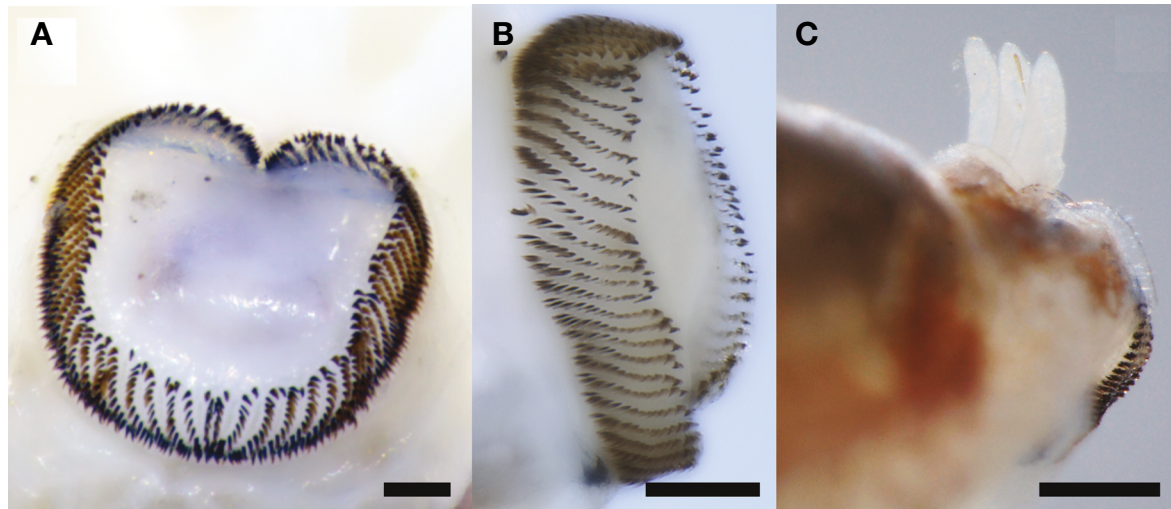
**Remarks.** This species is morphologically similar to *Simulium (Simulium) nikkoense* by having indistinct to negative head spots, postgenal cleft spear-head or miter shaped with

darkly pigmented. Morphological differences between them were discussed by Kim (2015a). Larvae were collected from a slow flowing small forest stream with artificial bedrock. They were collected along with 4 other black flies. The pupa of the species remains unknown.

***Simulium (Simulium) nikkoense* Shiraki, 1935  
(Figs. 6–8)**

*Simulium nikkoense* Shiraki, 1935: 77 (type locality: Nikko, Japan).

*Simulium noelleri*, not Friederichs: Takahasi, 1950: 1558



**Fig. 5.** *Simulium (Simulium) coreanum*. A, B, Hooks of posterior proleg; C, Rectal papillae, lateral view. Scale bars=0.1 mm (A, B), 0.2 mm (C).

(Japanese species).

*Simulium (Simulium) noelleri*, not Friederichs: Ogata and Sasa, 1954: 332 (Japanese list); 1955a: 11 (Japanese list and key).

*Simulium decorum*, not Walker: Benthinck, 1955: 11 (Korean and Japanese species and key).

*Simulium (Simulium) decorum*, not Walker: Ogata et al., 1956: 92 (Japanese species); Shogaki, 1956: 275 (Japanese list and taxonomy); Orii et al., 1969: 1–13 (Japanese key).

*Simulium (Simulium) nikkoense* [sic]: Takahasi, 1959: 636 (redescription).

*Simulium argyreatum triangulare* Rubtsov, 1963b: 548 (type localities: Honshu, Japan); Chow, 1973: 44 (Korean list).

*Simulium nikkoense*: Ono, 1982: 300 (Japanese key and taxonomy).

*Simulium (Simulium) nikkoense*: Uemoto, 1985: 332 (Japanese key and taxonomy); Rubtsov and Yankovsky, 1988: 182 (Palearctic catalogue); Crosskey and Howard, 2004: 65 (checklist); Uemoto, 2005: 1018 (Japanese key and taxonomy); Kim, 2013: 101 (Korean checklist); Adler and Crosskey, 2015: 92 (checklist); Kim, 2015a: 33 (redescription).

**Material examined.** Korea: Gangwon-do: Chuncheon-si, Dongsan-myeon, Wonchang-ri, 37°48'06"N, 127°46'52"E, 5 May 2010, Kim SK (7 ultimate, 13 penultimate, 4 early instar larvae, 14 pupae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: larval head spot positive but seemingly negative with darkly surrounding areas, hat shaped, postgenal cleft

miter shaped or lanceolate with apex extended to hypostomal groove; and pupal gill with 8 filaments arranged in (1 + 1 + 1) + 1 + (2 + 2), ventralmost filaments with long petiolate stalk.

**Description.** Mature larva (Fig. 6). Body length 6.9–8.1 mm (n = 10). Body (Fig. 6A) pale reddish brown with greyish inter-segmental areas. Head capsule (Fig. 6B–D) brownish yellow with brown to dark brown areas; head spots positive but seemingly negative due to dark surrounding areas, area surrounding head spots darkly pigmented, hat-shaped. Antenna (Fig. 6B) pale yellowish brown, as long as labral fan stem; distal article brown and darker than other articles. Labral fan (Fig. 6B, C) with 43–48 primary rays. Postgenal cleft (Fig. 6C) deep, miter shaped or lanceolate, pointed, 1.4 × as long as wide, 2.4–7.5 × as long as postgenal bridge; usually tip of postgenal cleft irregularly extended toward the hypostomal groove, lateral elongate spot present, positive. Lateral surface of head capsule (Fig. 6D) with positive spot under ocelli. Gill histoblast with 8 filaments (Fig. 6D). Hypostoma (Fig. 6E) with 9 apical teeth, 2 sublateral teeth indistinctive; median and lateral teeth prominent; sublateral teeth small, only 4 teeth visible; paralateral teeth not developed; lateral serrations well developed; hypostoma with 5–6 apically branched hypostomal setae. Posterior proleg (Fig. 7A, B) with 11–13 hooks in about 66–68 rows. Rectal papillae (Fig. 7C) of 3 lobes, each with 5–7 digit-like long secondary lobules.

Pupa (Fig. 8). Body length (excluding gill filaments) 3.5–4.4 mm (n = 10). Cocoon (Fig. 8A) slipper shaped with loosely woven rim, 5.0–6.5 mm long. Gill (Fig. 8B) with 8 filaments, 0.7 × as long as pupa (3.0–3.15 mm), (1 + 1 + 1)





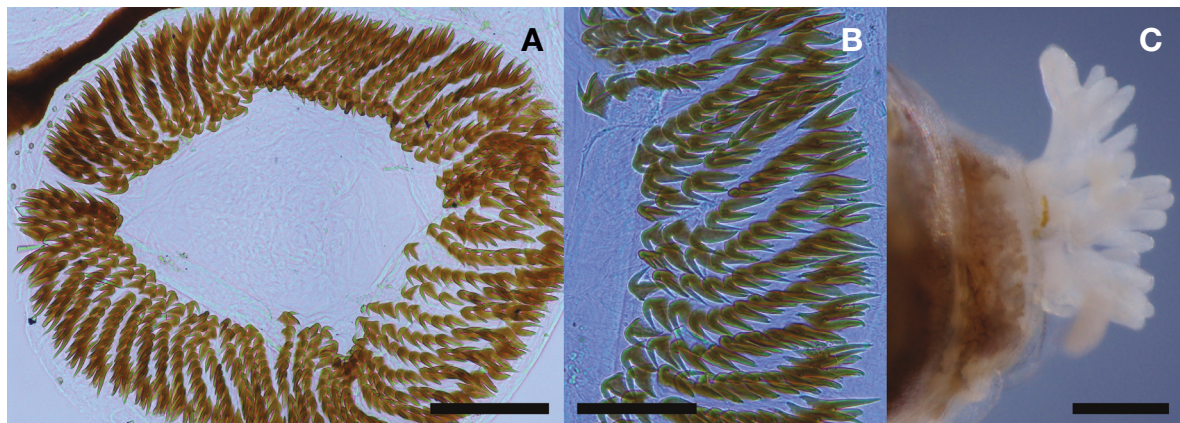
**Fig. 6.** *Simulium* (*Simulium*) *nikkoense*. A, Larva, lateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars=1 mm (A), 0.5 mm (B–D), 50  $\mu$ m (E).

+1 + (2+2) arrangement, arising from common short basal stem except two ventral pairs with long petiolate stalks; basalmost stalk longer than others; dorsalmost filament directed upwardly then forwardly, making an angle about  $90^\circ$ . Cephalic plates and thorax (Fig. 8C) densely covered with small tubercles. Frons with 2 short, simple trichomes; face 1 short, simple trichome. Thoracic trichomes in 6 pairs, simple, about  $1.4\times$  as long as cephalic trichomes. Abdomen (Fig. 8D) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segment V bare; segment VI with very small spines comb; segments VII–VIII with row of spine comb; terminal hooks

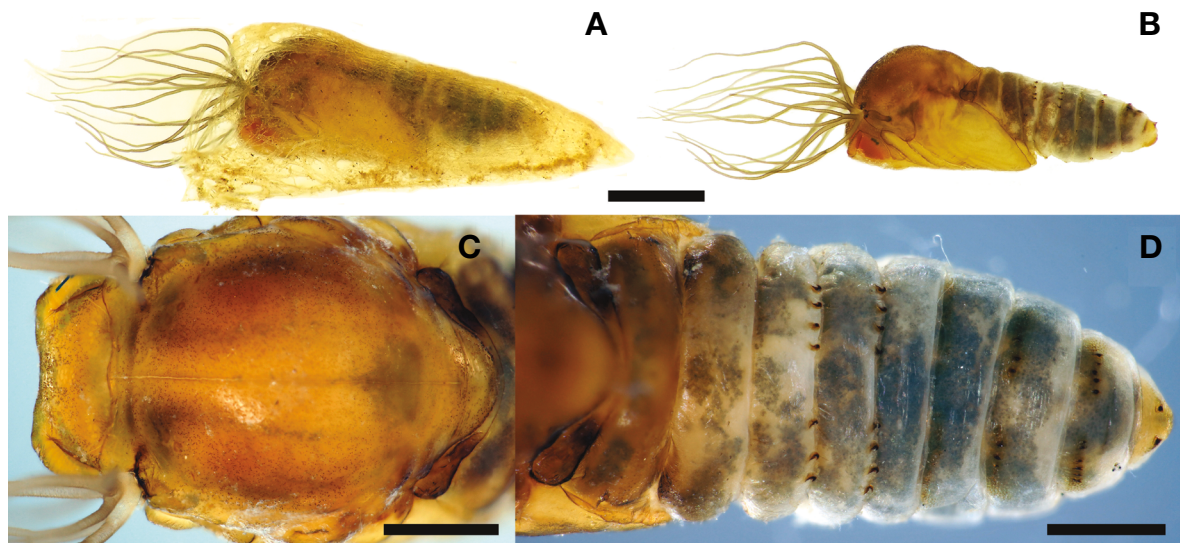
well developed.

**Distribution.** Korea, China, Japan.

**Remarks.** The examined specimens well fitted to the description and figure of Yoon and Song (1989) except size differences (5.0–5.8 mm vs. 7.0–8.1 mm). Mature larvae of Japanese specimens is about 7 mm long (Takahasi, 1959). Specimens were collected as pupae and larvae from a slow flowing lowland rocky stream with high content organic matter. Larvae and pupae were attached to the blades of the submerged grasses where the current was relatively fast. They were collected along with 3 other black fly species, *Simulium malyschevi*, *Simulium uchidai*, and *Simulium*



**Fig. 7.** *Simulium (Simulium) nikkoense*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, dorsal view. Scale bars=0.1 mm (A), 50  $\mu$ m (B), 0.2 mm (C).



**Fig. 8.** *Simulium (Simulium) nikkoense*. A, Pupa and cocoon, lateral view; B, Pupa, lateral view; C, Pupal head and thorax, dorsal view; D, Pupal abdomen, dorsal view. Scale bars=1 mm (A, B), 0.5 mm (C, D).

*suzukii*.

#### ***Griseifrons* species-group**

*Griseifrons* species-group contains 47 species which are recorded from Oriental and Palaearctic region (Adler and Crosskey, 2015). Single species is known to occur in Korea.

#### ***Simulium (Simulium) japonicum* Matsumura, 1931 (Figs. 9–11)**

*Simulium japonicum* Matsumura, 1931: 407 (type locality: Japan).

*Simulium colobatzensis* [sic], not Schoenbauer: Matsumura,

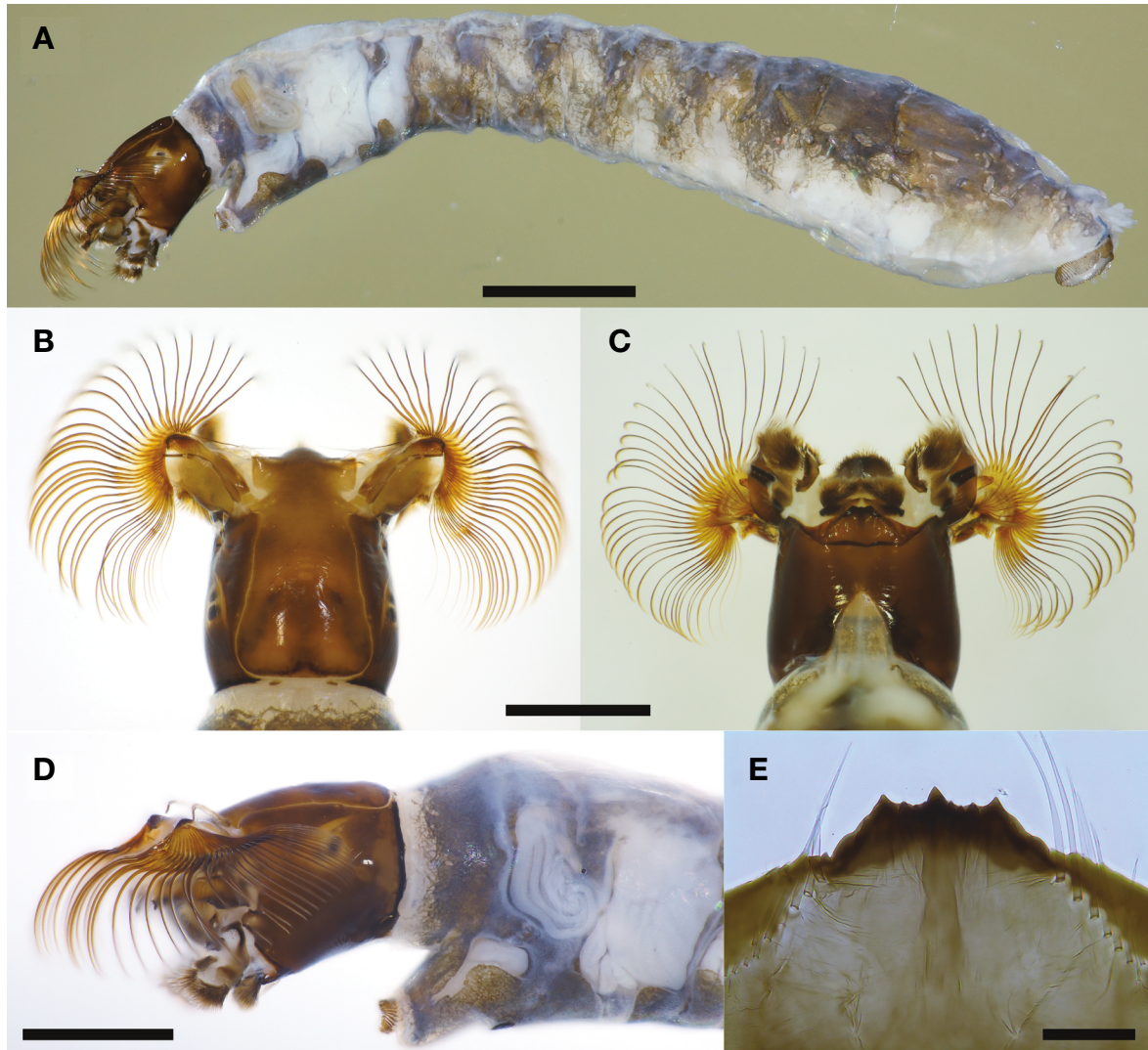
1915: 84.

*Simulium annulipes* Shiraki, 1935: 49 (type locality: Sapporo, Ziozankei, Hokkaido, Japan; Sachalin, Russia).

*Simulium oshimanum* Shiraki, 1935: 56 (type locality: Sumiyo, Amami-Oshima, Nansei Island, Japan).

*Simulium japonicum*: Kono and Takahasi, 1940: 81 (taxonomy); Takahasi, 1950: 1558 (adult description); Bentineck, 1955: 8 (Korean and Japanese species and key); Rubtsov, 1963b: 540 (taxonomy); 1969: 193 (female description); Chow, 1973: 45 (Korean list); Poinar and Saito, 1979: 147 (ecology); Ono, 1982: 298 (Japanese key and taxonomy); Baba and Takaoka, 1985: 71 (ecology); Sasaki et al., 1988:





**Fig. 9.** *Simulium (Simulium) japonicum*. A, Larva, lateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars=1 mm (A), 0.5 mm (B–D), 50  $\mu$ m (E).

87 (ecology); Baba and Takaoka, 1989: 307 (ecology); Paek et al., 2010: 221 (Korean list); Takaoka et al., 2012: 374 (ecology).

*Simulium (Simulium) japonicum*: Ogata and Sasa, 1954: 332 (Japanese list); 1955a: 11 (Japanese key); Ogata and Sasa, 1955b: 40 (Japanese list); Anonymus, 1965: 192 (redescription in Japanese); Anonymus, 1974: 192 (Japanese list); Takaoka, 1974: 145 (key and taxonomy); 1977a: 201 (redescription); 1977b: 219 (Japanese key); Uemoto, 1985: 332 (Japanese key and taxonomy); 2005: 1018 (Japanese key and taxonomy); Takaoka and Okazawa, 1988: 101 (Japanese list); Yoon and Song, 1989: 41 (redescription); Crosskey et al., 1996: 426 (Chinese checklist); Crosskey

and Howard, 2004: 59 (checklist); Kim, 2011b: 208 (redescription); 2013: 100 (Korean checklist); Adler and Crosskey, 2015: 84 (checklist).

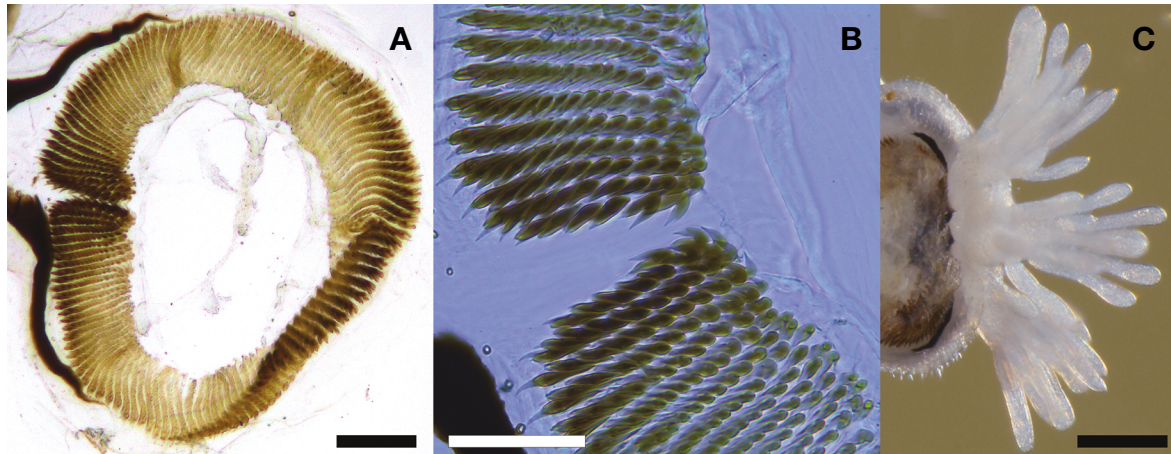
*Simulium kurilense* Rubtsov, 1956: 767 (type localities: Siberia (Kurile Island)).

*Simulium (Simulium) japonica*: Takahasi, 1959: 636 (redescription).

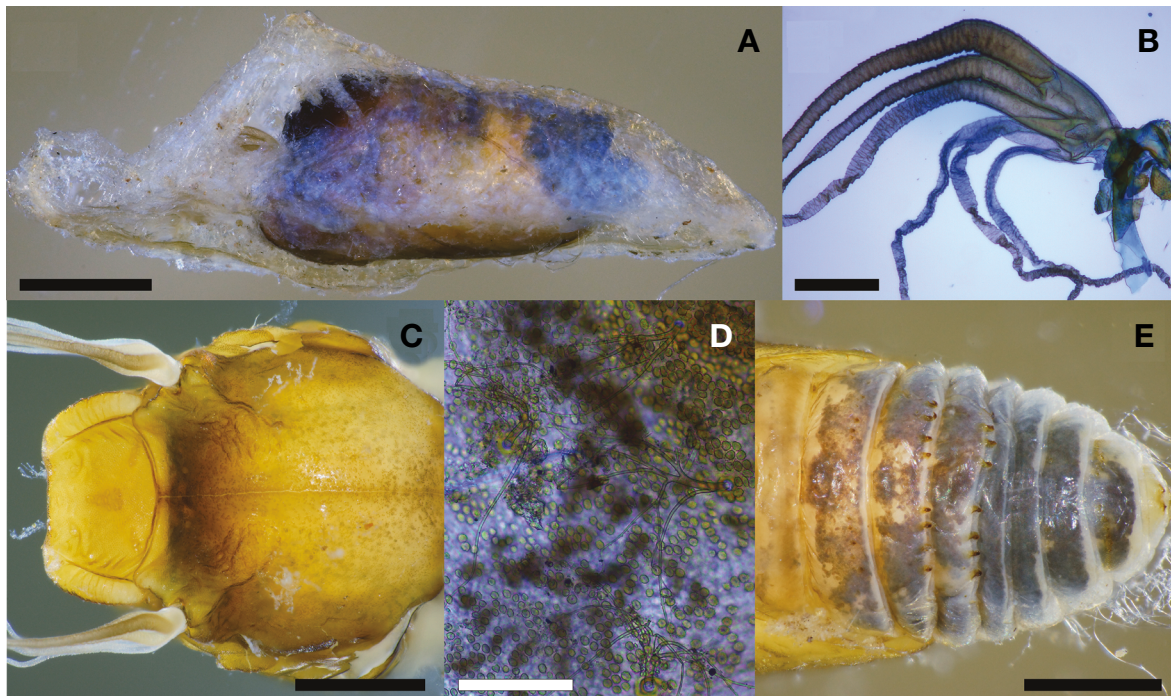
*Simulium (Striatosimulium) japonicum*: Rubtsov and Yankovsky, 1988: 179 (Palearctic catalogue).

**Material examined.** Korea: Gangwon-do: Chuncheon-si, Sabuk-myeon, Jiam-ri, 37°58'05"N, 127°34'43"E, 24 Apr 2010, Kim SK (80 ultimate/penultimate, 112 early instar lar-





**Fig. 10.** *Simulium (Simulium) japonicum*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, postero-ventral view. Scale bars=0.1 mm (A), 50  $\mu$ m (B), 0.2 mm (C).



**Fig. 11.** *Simulium (Simulium) japonicum*. A, Pupa and cocoon, lateral view; B, Gill filaments, phase-contrast micrograph; C, Pupal head and thorax, dorsal view; D, Thoracic trichomes, phase-contrast micrograph; E, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.2 mm (B), 0.5 mm (C, E), 0.1 mm (D).

vae; 4 pupae); Chuncheon-si, Dong-myeon, Gamjeong-ri, 37°54'05"N, 127°47'60"E, 25 Apr 2010, Kim SK (55 ultimate/penultimate, 11 early instar larvae; 18 pupae); Chuncheon-si, Sinbuk-eup, Balsan-ri, 37°58'03"N, 127°46'21"E, 9 May 2010, Kim SK (56 ultimate/penultimate, 18 early instar larvae); Wonju-si, Panbu-myeon, Seogok-ri, Yongsu-gol valley, 37°16'33"N, 127°56'51"E, 15 May 2010, Kim SK

(12 ultimate/penultimate, 4 early instar larvae; 20 pupae); Jeongseon-gun, Bukpyeong-myeon, Bukpyeong-ri, 37°28'33"N, 128°39'44"E, 20 Apr 2012, Kim SK (189 ultimate/penultimate, 240 early instar larvae, 7 pupae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon shoe shaped with single large lateral

aperture, gill of 6 filaments; and larvae with postgenal cleft triangular, head capsule dark brown.

**Description.** Mature Larva (Fig. 9). Body length 7.0–7.7 mm (n=20). Body (Fig. 9A) greyish brown. Head capsule (Fig. 9B–D) dark brown ground color with positive head spots, anteromedial spot faint, negative. Antenna (Fig. 9D) brown, distal article darker than other articles, extended beyond apex of labral fan stem by about 1/2 length of distal article, median article ventrally pale. Labral fan (Fig. 9B, C) with 37–42 primary rays. Postgenal cleft (Fig. 9C) triangular, pointed apically, as long as wide, 2× as long as postgenal bridge, laterally with elongate positive spot; subesophageal ganglion darkly pigmented. Lateral surface of head capsule (Fig. 9D) with positive, but seemingly negative spots under ocelli. Gill histoblast with 6 filaments (Fig. 9D). Hypostoma (Fig. 9E) with 9 apical teeth; median tooth prominent, lateral teeth smaller than median tooth; sublateral teeth small, indistinctive; 1 paralateral teeth weakly developed; lateral serrations well developed; hypostoma with 7–8 simple hypostomal setae. Posterior proleg (Fig. 10A, B) with 12–15 hooks in about 110–125 rows. Rectal papillae (Fig. 9C) of 3 lobes, each with 8–12 digit-like long secondary lobules.

Pupa (Fig. 11). Body length (excluding gill filaments) 3.0–3.7 mm (n=20). Cocoon (Fig. 11A) shoe shaped with single large lateral aperture, embracing gill filaments completely, 4.8–5.8 mm long. Gill (Fig. 11B) with 6 filaments, about half as long as pupa (1.5–2.1 mm); upper 3 filaments yellowish brown, lower 3 filaments pale; dorsalmost pair stalked, others sessile. Cephalic plates and thorax (Fig. 11C) densely covered with small tubercles. Frons with 2 short, branched trichomes; face 1 short, branched trichome. Thoracic trichomes (Fig. 11D) in 6 pairs, long and branched (4- to 7-branched), about 1.5× as long as cephalic trichomes. Abdomen (Fig. 11E) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segments V–VII without spines; segment VIII with row of small spine comb; terminal hooks well developed.

**Distribution.** Korea, China, Japan, Siberia.

**Remarks.** Adults of this species are known to feed blood from three mammalian species, viz., human, cattle and horse (Takaoka, 1977a; Sasaki et al., 1988). Nine larval instars were identified for this species based on the measurements of head capsules of laboratory-reared individuals (Baba and Takaoka, 1989). This species showed some degree of morphological plasticity. Most larvae have head capsule dark brown but in some cases with light or yellow brown; specimens with dark brown head capsule usually have negative anteromedial head spot, but in specimens with light brown or yellowish brown head spot, all head spots are positive. Subesophageal ganglion is usually darkly pig-

mented, not always. This species is widely distributed in many types of streams. There seems to be no specific or preferred types of habitats for this species. Larvae usually attached to the rocks where the riffle occurred. They were frequently infected with unidentified mermithid nematodes, microsporidian fungi, and *Coelomycidium simulii* fungus. For instance, about 47% of collected larvae (34 out of 73 larvae) were infected with mermithid nematodes in a single stream.

#### *Malyschevi* species-group

*Malyschevi* species-group contains 40 species plus over 20 cytoforms from the world (Adler and Crosskey, 2015). Two species are known to occur in Korea.

#### *Simulium (Simulium) malyschevi* Dorogostaisky, Rubtsov & Vlasenko, 1935 (Figs. 12–14)

*Simulium malyschevi* Dorogostaisky, Rubtsov and Vlasenko, 1935: 142 (Type locality: Ushakovka river near Irkutsk, Russia).

*Simulium (Simulium) malyschevi*: Sommerman, 1953: 260 (in key to Alaskan black fly larvae); Currie, 1986: 45 (taxonomy and ecology); Yoon and Song, 1989: 38 (redescription); Crosskey et al., 1996: 424 (Chinese checklist); Crosskey and Howard, 2004: 62 (checklist); Adler et al., 2004: 392 (taxonomy); Kim, 2013: 100 (Korean checklist); Adler and Crosskey, 2015: 88 (checklist).

*Simulium malyschevi*: Ogata, 1954: 108 (ecology); Bentinck, 1955: 11 (Korean and Japanese species and key); Chow, 1973: 45 (Korean list); Paek et al., 2010: 221 (Korean list).

*Simulium (Gnus) malyschevi* [sic]: Ogata and Sasa, 1954: 331 (Japanese list); 1955a: 10 (Japanese key); Ogata and Sasa, 1955b: 40 (Japanese list); Anonymus, 1965: 192 (redescription in Japanese); Anonymus, 1974: 192 (Japanese list); Uemoto, 1985: 331 (Japanese key and taxonomy); 2005: 1033 (Japanese key and taxonomy); Takaoka and Okazawa, 1988: 101 (Japanese list).

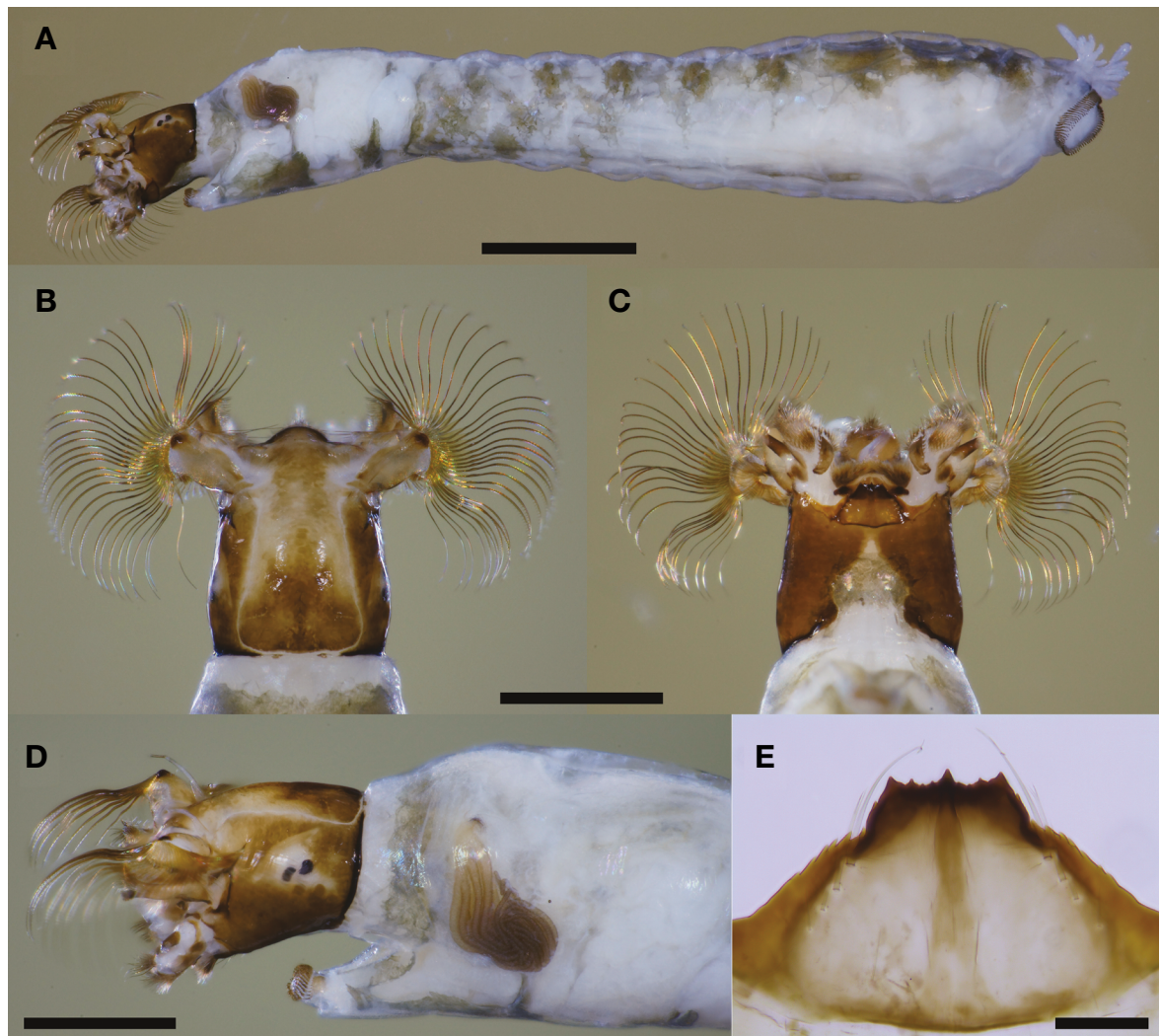
*Gnus malyschevi* [sic] *albipes* Rubtsov, 1956: 615 (type localities: Primor'ye Territory, Barabash, Kedrovaya Pad Reserve, Russia).

*Gnus malyschevi* [sic] *lucidum* Rubtsov, 1956: 616 (type localities: Angara River, Pashki, Russia).

*Gnus malyschevi*: Rubtsov, 1969: 155 (redescription); Rubtsov and Yankovsky, 1988: 162 (Palearctic catalogue).

**Material examined.** Korea: Gangwon-do: Hwacheon-gun, Sanae-myeon, Yongdam-ri, 38°03'14"N, 127°32'54"E, 7 May 2010, Kim SK (578 ultimate/penultimate, 84 early instar larvae; 73 pupae); Chuncheon-si, Dong-myeon, Sini-ri, 37°53'01"N, 127°50'46"E, 8 May 2010, Kim SK (270





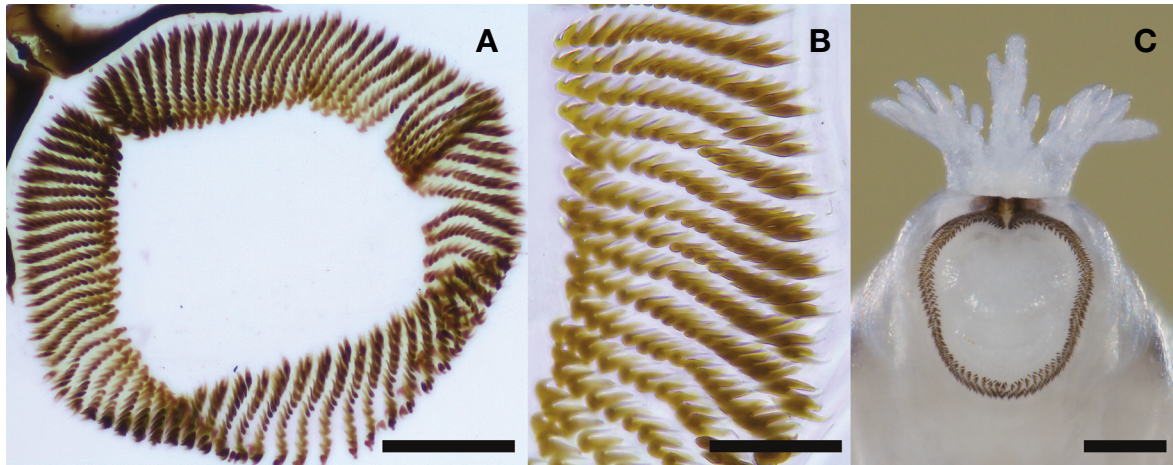
**Fig. 12.** *Simulium* (*Simulium*) *malyschevi*. A, Larva, ventrolateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars=1 mm (A), 0.5 mm (B–D), 50 µm (E).

ultimate/penultimate, 5 early instar larvae; 61 pupae); Hongcheon-gun, Hwachon-myeon, Guseongpo-ri, 37°48'21"N, 127°54'29"E, 28 Jun 2010, Kim SK (65 ultimate/penultimate, 55 early instar larvae; 5 pupae).

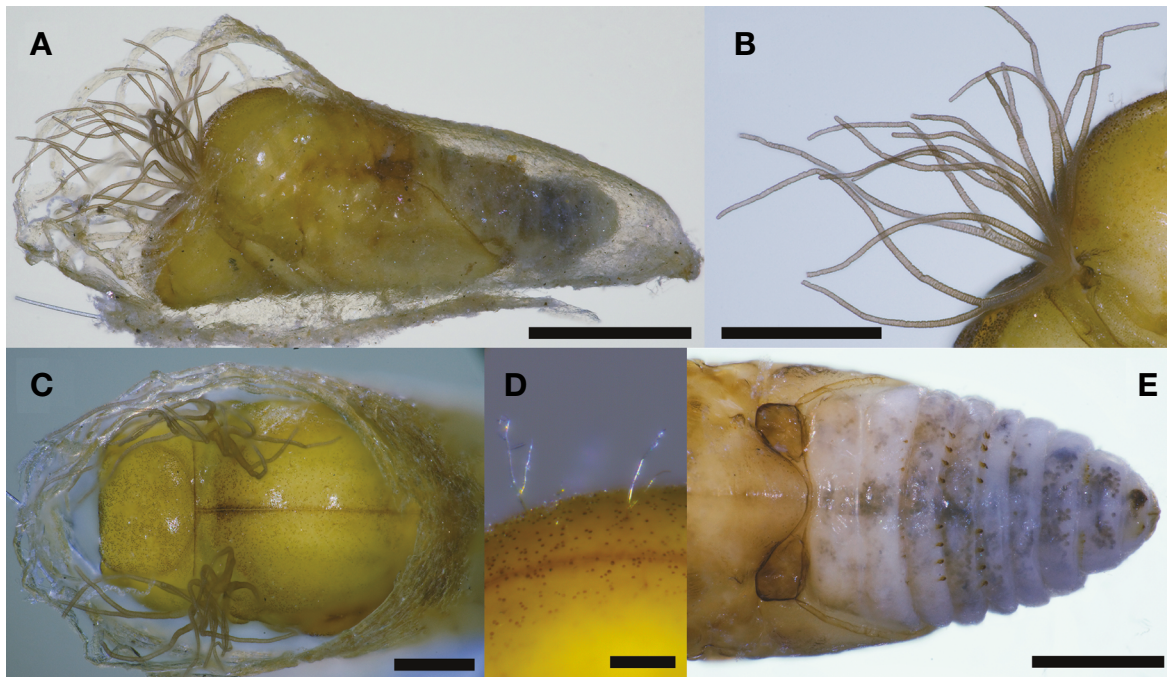
**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon boot shaped with many lateral apertures, gill of 16 filaments; and larvae with miter shaped postgenal cleft almost reaching to hypostomal groove.

**Description.** Mature Larva (Fig. 12). Body length 5.8–6.2 mm (n=20). Body (Fig. 12A) pale with grey to greyish green patterns. Head capsule (Fig. 12B–D) brown to dark brown ground color with positive head spots; anteromedial spots distinctive, anterolateral spots fused. Antenna (Fig. 12B,

D) pale to yellowish brown, distal article brown, extended beyond apex of labral fan stem by about 1/3 of distal article, median article ventrally pale. Labral fan (Fig. 12B, C) with 35–39 primary rays. Postgenal cleft (Fig. 12C) miter shaped, extending to hypostomal groove, as long as wide, darkly pigmented, lateral spot absent; postgenal bridge almost absent; subesophageal ganglion darkly pigmented. Lateral surface of head capsule (Fig. 12D) with 3 distinct positive spots under ocelli. Gill histoblast with 16 filaments (Fig. 12D). Hypostoma (Fig. 12E) with 9 apical teeth; median tooth prominent, lateral teeth smaller than median tooth; sublateral teeth small; 1–2 paralateral teeth developed; lateral serrations well developed; hypostoma with 4–5 apically branched hypostomal setae. Posterior proleg (Fig. 13A, B)



**Fig. 13.** *Simulium (Simulium) malyschevi*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, postero-ventral view. Scale bars=0.1 mm (A), 50  $\mu$ m (B), 0.2 mm (C).



**Fig. 14.** *Simulium (Simulium) malyschevi*. A, Pupa and cocoon, lateral view; B, Pupal gill filaments, lateral view; C, Pupal head and thorax, dorsal view; D, Pupal thoracic trichomes, dorsolateral view; E, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.5 mm (B, C, E), 0.1 mm (D).

with 12–14 hooks in about 72–78 rows. Rectal papillae (Fig. 13C) of 3 lobes, each with 5–10 digit-like long secondary lobules.

Pupa (Fig. 14). Body length (excluding gill filaments) 2.5–3.1 mm ( $n=20$ ). Cocoon (Fig. 14A) boot shaped with many lateral apertures, partly or completely embracing gill filaments, 3.7–4.3 mm long. Gill (Fig. 14B) with 16 fila-

ments, short, about 1/3 as long as pupal body length (0.8–1.3 mm); each filaments paired in long stalks. Cephalic plates and thorax (Fig. 14C) moderate to densely covered with small tubercles. Frons with 2 short, simple trichomes; face with 1 short, simple trichome. Thoracic trichomes (Fig. 14D) in 6 pairs, long and branched/unbranched, about 2 $\times$  as long as cephalic trichomes. Abdomen (Fig. 14E) with



each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segments V–VII without spines; segment VIII with row of small spine comb; terminal hooks weakly to moderately developed.

**Distribution.** Korea, China, Japan, Siberia, USA.

**Remarks.** Body color of alcohol preserved larvae usually showed pale with grey to greyish green patterns, but pale ground color with yellow and reddish brown patterns observed in fresh larvae. Color of head spot also varied among specimens. This species is the only Korean species recorded from the North America. The number of filaments in the pupal gill is typically 16 (always 16 in Korean specimens), but varies from 13 to 16 (rarely 12) in Nearctic populations (Adler et al., 2004). This species was sporadically collected from different streams in different seasons but primarily large numbers of larvae and pupae were collected from large fast-flowing streams. For instance, over 200 larvae and pupae were attached to a single rock in fast flowing large river-like stream. Larvae were infrequently infected with a fungus, *Coelomycidium simulii* (2 out of 277 larvae in a

single stream).

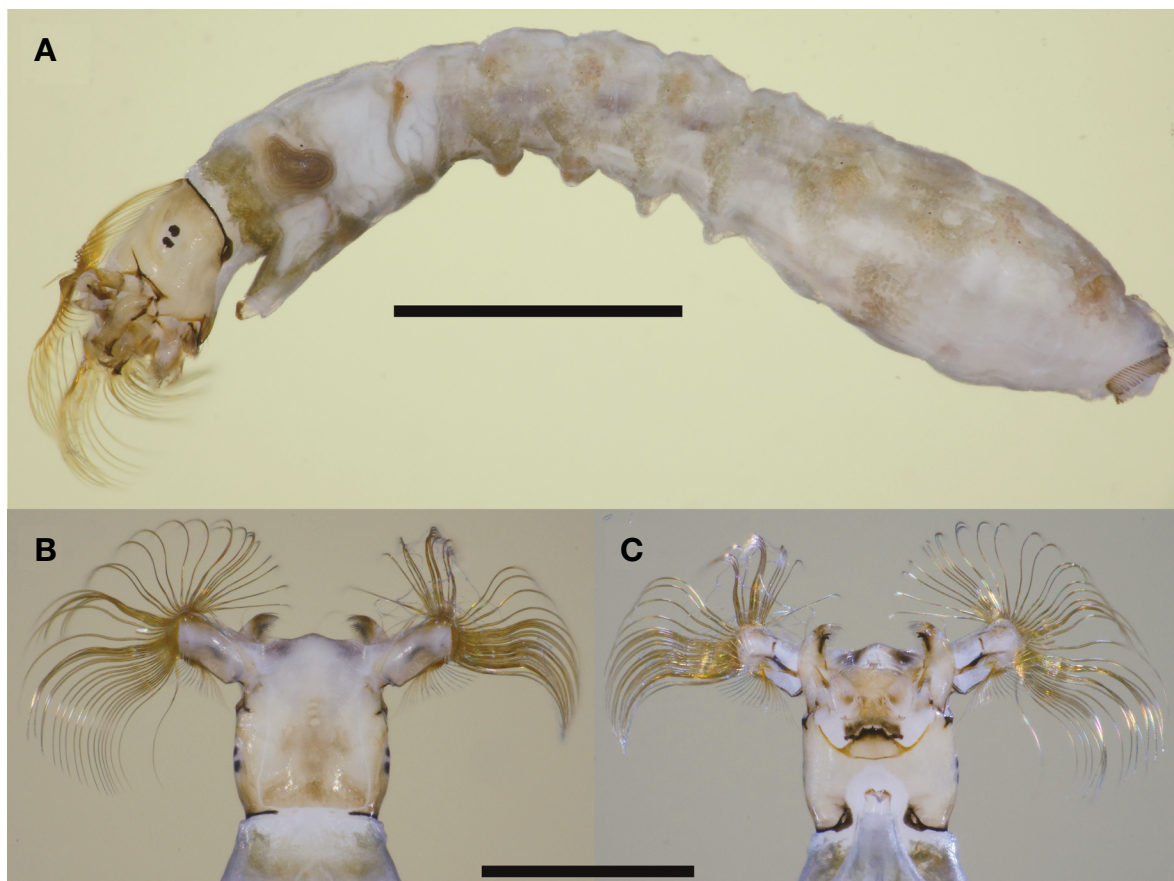
***Simulium (Simulium) nacojapi* Smart, 1944  
(Figs. 15–17)**

*Odagmia japonica* Shiraki, 1935: 45 (type localities: Jifuku, Yamaguchi-Pref, Nakagawara, Tottori-Pref, Yokote, Shimane-Pref, Japan) [junior secondary homonym of *S. japonicum* Matsumura, 1931: 407].

*Simulium nacojapi* Smart, 1944: 133 [replacement name]; Shogaki, 1956: 274 (Japanese list and taxonomy); Chow, 1973: 45 (Korean list); Paek et al., 2010: 221 (Korean list).

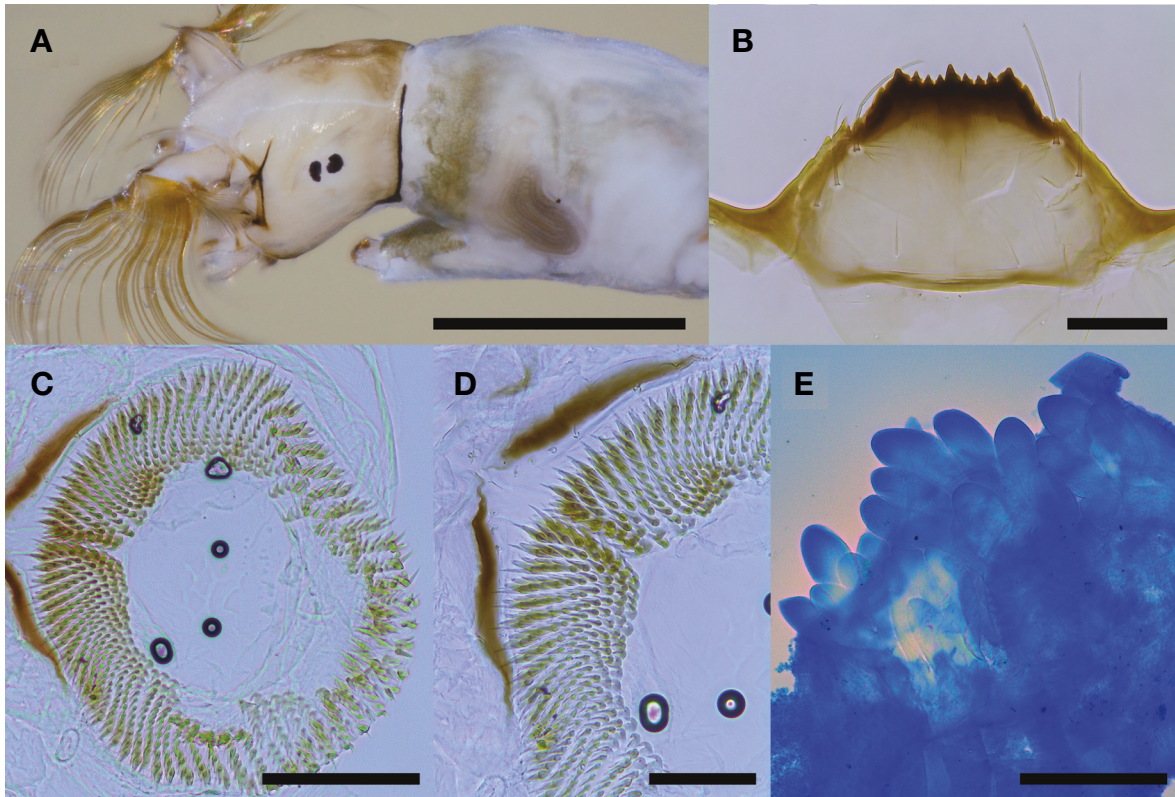
*Gnus japonicus*: Takahasi, 1950: 1558 (Japanese list and taxonomy).

*Simulium (Gnus) nacojapi*: Ogata and Sasa, 1954: 331 (Japanese list); 1955a: 10 (Japanese key); Ogata et al., 1956: 86 (taxonomy and ecology); Anonymus, 1965: 192 (redescription in Japanese); Uemoto, 1985: 331 (Japanese key and taxonomy); 2005: 1018 (Japanese key and taxonomy); Takaoka and Okazawa, 1988: 101 (synonym list); An,

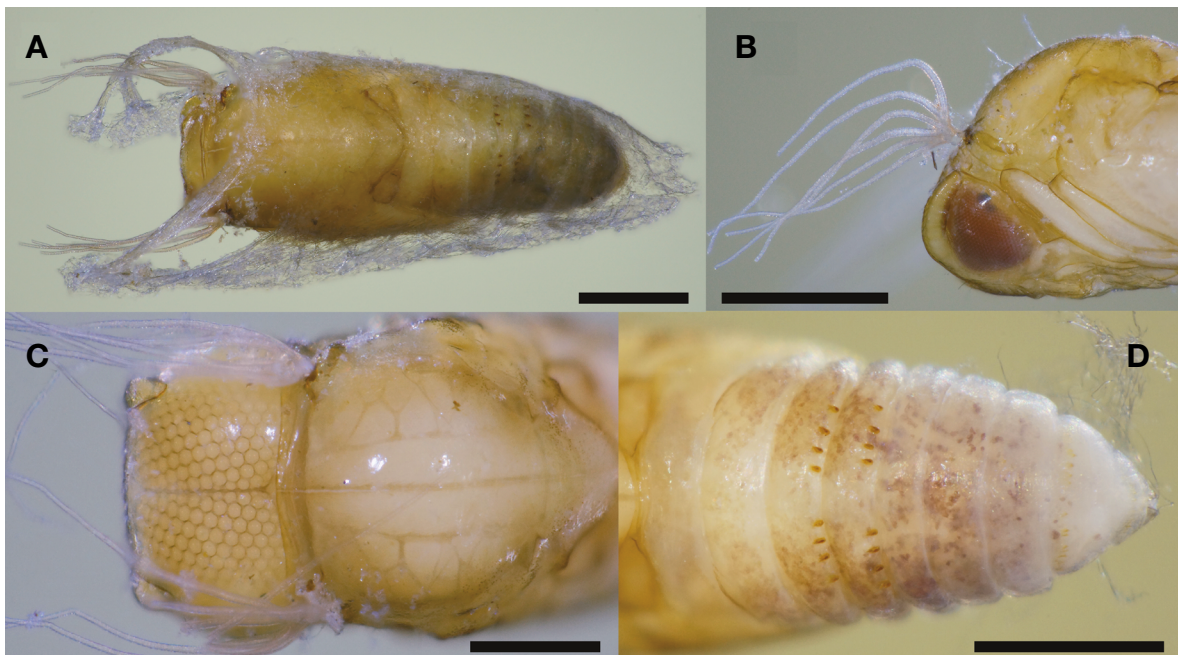


**Fig. 15.** *Simulium (Simulium) nacojapi*. A, Larva, lateral view; B, Larval head, dorsal view; C, Larval head, ventral view. Scale bars = 1 mm (A), 0.5 mm (B, C).





**Fig. 16.** *Simulium* (*Simulium*) *nacojapi*. A, Larval head and gill histoblast, dorsolateral view; B, Larval hypostoma, phase-contrast micrograph; C, D, Hooks of posterior proleg, phase-contrast micrographs; E, Rectal papillae, phase-contrast micrograph. Scale bars=0.5 mm (A), 50 µm (B, D), 0.1 mm (C, E).



**Fig. 17.** *Simulium* (*Simulium*) *nacojapi*. A, Pupa and cocoon, dorsolateral view; B, Pupal gill filaments, lateral view; C, Pupal head and thorax, dorsal view; D, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.5 mm (B-D).

1989: 185 (Chinese list).

*Simulium subvariegatum*, not Rubtsov: Bentinck, 1955: 10 (Korean and Japanese species and key).

*Gnus nacojapi*: Rubtsov, 1962: 433 (taxonomy); Rubtsov and Yankovsky, 1988: 162 (Palearctic catalogue).

*Simulium (Simulium) nacojapi*: Yoon and Song, 1989: 37 (pupal redescription); Crosskey et al., 1996: 424 (taxonomy); Crosskey and Howard, 2004: 62 (checklist); Kim, 2013: 100 (Korean checklist); Adler and Crosskey, 2015: 89 (checklist).

**Material examined.** Korea: Gangwon-do: Hongcheon-gun, Seo-myeon, Eoyupo-ri, 37°42'57"N, 127°41'59"E, 10 Jun 2010, Kim SK (1 pupa); Hongcheon-gun, Hwachon-myeon, Guseongpo-ri, 37°48'21"N, 127°54'29"E, 28 Jun 2010, Kim SK (1 ultimate instar larva; 8 pupae); Hongcheon-gun, Bukbang-myeon, Seongdong-ri, 37°44'46"N, 127°53'02"E, 28 Jun 2010, Kim SK (3 pupae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon slipper shaped with single lateral aperture, gill of 6 filaments; and larvae with large bulbous postgenal cleft.

**Description.** Mature Larva (Fig. 15). Body length 4.1 mm ( $n = 1$ ). Body (Fig. 15A) pale with greenish grey patterns. Head capsule (Figs. 15B, C, 16A) pale yellow ground color with positive, but seemingly negative head spots due to relatively dark surrounding areas; anteromedial spots separated, negative, anterolateral spots fused. Antenna (Fig. 15B) pale to yellowish brown, extended beyond apex of labral fan stem by about 1/3 of distal article. Labral fan (Fig. 15B, C) with 43 primary rays. Postgenal cleft (Fig. 15C) large, bulbous, 1.2× as long as wide, lateral spot faint, almost reaching to hypostomal groove; postgenal bridge short (0.01 mm). Lateral surface of head capsule (Figs. 15A, 16A) with single faint spot under ocelli. Gill histoblast with 6 filaments (Fig. 16A). Hypostoma (Fig. 16B) with 9 apical teeth; median tooth prominent, lateral teeth smaller than median tooth; sublateral teeth well developed; 1–2 paralateral teeth developed; lateral serrations well developed; hypostoma with 3 apically branched hypostomal setae. Posterior proleg (Fig. 16C, D) with 10–11 hooks in 76 rows. Rectal papillae (Fig. 16E) of 3 lobes, each with 5–8 thumb-like secondary lobules.

Pupa (Fig. 17). Body length (excluding gill filaments) 1.9–2.2 mm ( $n = 10$ ). Cocoon (Fig. 17A) slipper shaped with single lateral aperture, 2.4–3.0 mm long. Gill (Fig. 17B) with 6 filaments, about 0.6× as long as pupa (1.0–1.5 mm); dorsalmost filament directed upwardly then forwardly, angle between dorsalmost filament and ventralmost filament little over 90°. Cephalic plates and thorax (Fig. 16C) without

tubercles. Frons with 2 short, simple trichomes; face with 1 short, simple trichome. Thoracic trichomes (Fig. 17B) in 6 pairs, long and simple, about 1.5–2× as long as cephalic trichomes. Abdomen (Fig. 17D) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segments V–VI without spines; segment VII with weakly developed spine comb, but sometimes indistinctive; segment VIII with row of small spine comb; terminal hooks not developed.

**Distribution.** Korea, China, Japan, Siberia.

**Remarks.** This species is rarely collected from Korea. A total of 12 pupae were collected from 3 localities but only a single larva was available. Yoon and Song (1989) also collected pupae from 13 localities but they failed to collect larva. This species was collected from lowland, moderately flowing streams with well-developed trailing grasses where the larva and pupae were attached. They were collected along with 7 other black fly species. This species is the most common species in the northern suburbs of Kyoto-city and bites human and domestic animals violently in Japan (Shogaki and Yoshida, 1956).

#### *Ornatum* species-group

*Ornatum* species-group contains 24 species plus 9 cytoforms, 7 subspecies, and 1 morphoform from the world (Adler and Crosskey, 2015). Single species is known to occur in Korea.

#### *Simulium (Simulium) iwataense* (Shiraki, 1935) (Figs. 18–20)

*Odagmia iwataensis* Shiraki, 1935: 40 (type locality: Iwate, Japan).

*Simulium (Odagmia) ornatum*, not Meigen: Ogata and Sasa, 1954: 331 (Japanese list); 1955a: 11 (Japanese key); Ogata and Sasa, 1955b: 40 (Japanese list); Ogata et al., 1956: 82 (redescription); Takahasi, 1959: 635 (redescription); Traeger et al., 1960: 5 (taxonomy); Anonymus, 1965: 191 (redescription in Japanese).

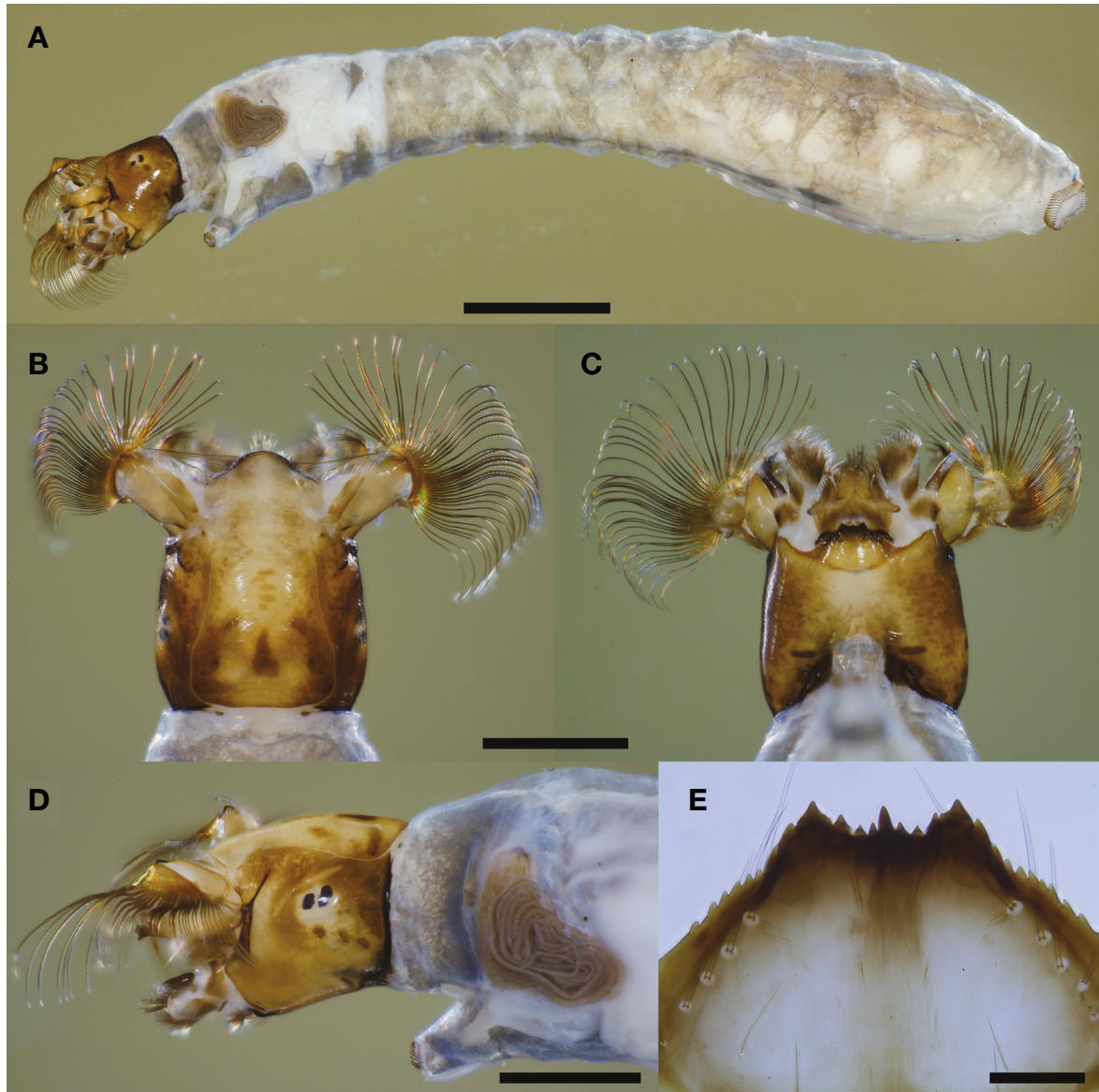
*Simulium ornatum*, not Meigen: Bentinck, 1955: 15 (Korean and Japanese species and key).

*Simulium (Odagmia) iwataense*: Anonymous, 1974: 192 (Japanese list); Takahasi, 1974: 295 (taxonomy); Takaoka, 1974: 145 (Korean record and key); Uemoto, 1985: 331 (Japanese key and taxonomy); 2005: 1018 (Japanese key and taxonomy); Takaoka and Okazawa, 1988: 100 (Japanese list).

*Phoretodagmia iwataensis*: Rubtsov and Yankovsky, 1988: 172 (Palearctic catalogue).

*Simulium (Simulium) iwataense*: Crosskey et al., 1996: 428 (Chinese checklist); Otsuka et al., 2003: 114 (phylogeny); Crosskey and Howard, 2004: 67 (checklist); Kim, 2011a:





**Fig. 18.** *Simulium* (*Simulium*) *iwatense*. A, Larva, ventrolateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars = 1 mm (A), 0.5 mm (B-D), 50  $\mu$ m (E).

204 (redescription); 2013: 100 (Korean checklist); Adler and Crosskey, 2015: 93 (checklist).

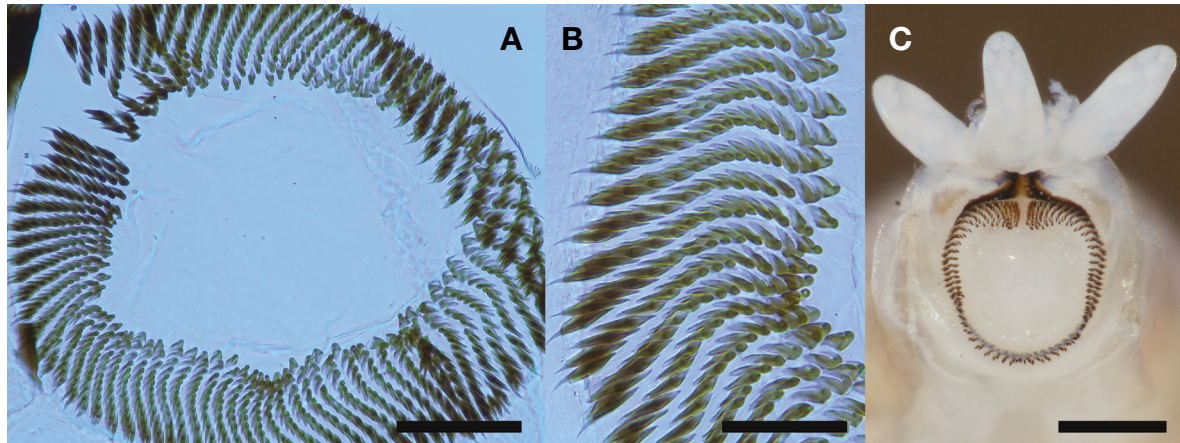
*Simulium iwatense*: Yamashita et al., 2000: 33 (ecology).

**Material examined.** Korea: Gangwon-do: Chuncheon-si, Dongnae-myeon, Saam-ri, 37°49'56"N, 127°46'52"E, 5 Nov 2009, SK Kim (60 ultimate/penultimate, 155 early instar larvae; 9 pupae); Chuncheon-si, Namsan-myeon, Changchon-ri, 37°46'37"N, 127°38'35"E, 21 May 2010, Kim SK (74 ultimate/penultimate, 42 early instar larvae); Chuncheon-si, Dongnae-myeon, Sinchon-ri, 37°51'32"N, 127°47'

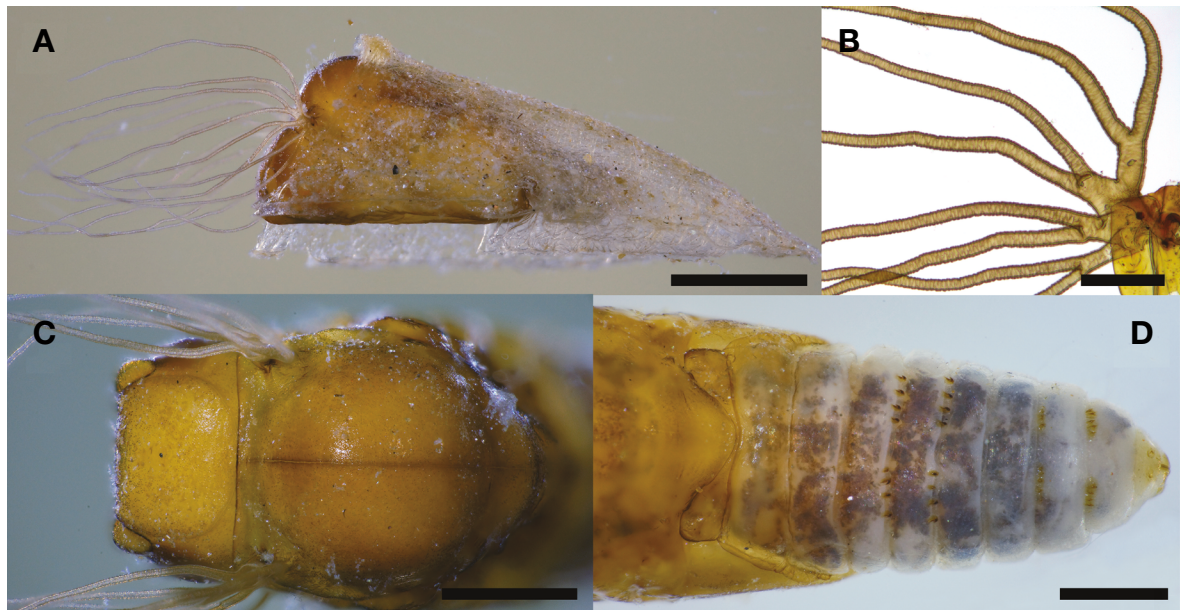
28"E, 15 Jun 2010, Kim SK (45 ultimate/penultimate, 30 early instar larvae; 60 pupae); Jeju-do: Seogwipo-si, Seogwi-dong, Donghongcheon stream, 33°14'40"N, 126°34'24"E, 10 Oct 2012, Kim SK (6 ultimate/penultimate, 5 early instar larvae; 14 pupae); Seogwipo-si, Haye-dong, Yerae Eco Park, 33°14'39"N, 126°23'27"E, 11 Oct 2012, Kim SK (37 ultimate/penultimate, 21 early instar larvae; 7 pupae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon slipper shaped, gill of 8 filaments arranged 2 + 2 + 2 + 2 and each with short stalk; and larvae





**Fig. 19.** *Simulium (Simulium) iwatense*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, posterior view. Scale bars=0.1 mm (A), 50 µm (B), 0.2 mm (C).



**Fig. 20.** *Simulium (Simulium) iwatense*. A, Pupa and cocoon, lateral view; B, Gill filaments, phase-contrast micrograph; C, Pupal head and thorax, dorsal view; D, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.2 mm (B), 0.5 mm (C, D).

with shallow postgenal cleft as long as or shorter than postgenal bridge, positive head spots, and 3 simple rectal papillae.

**Description.** Mature larva (Fig. 18). Body length 5.7–8.0 mm ( $n=30$ ). Body (Fig. 18A) greyish brown or yellowish brown with grey pigmentation. Head capsule (Fig. 18B–D) yellowish brown to brown ground color, mottled with numerous dark spots; head spots positive, distinctive; antero-omeidial spots distinctive, separated, paler than other spots; anterolateral spots fused; posteromedial spots darkest.

Antenna (Fig. 18B) pale yellow to light brown, distal article brown, median article with hyaline band, extended beyond apex of labral fan stem by about 1/2 of distal article. Labral fan (Fig. 18B, C) with 34–43 primary rays. Postgenal cleft (Fig. 18C) shallow, apically round, as long as wide, as long as or little shorter than postgenal bridge, usually the shape of postgenal cleft not clearly defined; distinct positive elongate lateral spot present; subesophageal ganglion darkly pigmented. Lateral surface of head capsule (Fig. 18D) with diagonally arranged 3 distinct spots under ocelli. Gill

histoblast with 8 filaments (Fig. 18D). Hypostoma (Fig. 18E) with 9 apical teeth; lateral teeth most prominent, median tooth smaller than the lateral teeth; sublateral teeth well developed; 2 paralateral teeth developed; 6 lateral serrations well developed; hypostoma with 4–6 apically branched hypostomal setae. Posterior proleg (Fig. 19A, B) with 12–14 hooks in about 75–84 rows. Rectal papillae (Fig. 19C) of 3 simple lobes.

Pupa (Fig. 20). Body length (excluding gill filaments) 2.9–3.6 mm ( $n = 20$ ). Cocoon (Fig. 20A) slipper shaped, 3.9–5.2 mm long. Gill (Fig. 20B) with 8 filaments, 2 + 2 + 2 + 2 arrangement, little shorter than pupa (2.2–2.6 mm); each filaments paired in short stalks; stalks of dorsal 2 pairs thicker than ventral 2 pairs; dorsalmost filament and ventralmost filament widely divergent, angle between dorsalmost and ventralmost filaments about 150°. Cephalic plates and thorax (Fig. 20C) moderate to densely covered with small tubercles. Frons with 2 short, simple trichomes; face with 1 short, simple trichome. Thoracic trichomes in 6 pairs, long and simple, about 2 × as long as cephalic trichomes. Abdomen (Fig. 20D) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segments V–VI without spines; segments VII–VIII with row of spine combs; terminal hooks moderately developed.

**Distribution.** Korea, China, Japan, Siberia.

**Remarks.** Body color of preserved larvae changed and differed from dark-colored fresh larvae; greyish brown or yellowish brown with grey pigmentation in preserved larvae whereas brown to dark brown with dark head in fresh larvae. This species was first recorded from Jeju Island by Takaoka (1974). Ultimate instar larvae and pupae were collected on May (Takaoka, 1974) and majority of larvae and pupae were collected from May to November. Over 20 pupae were collected on October in Jeju Island, assuming at least bivoltine, possibly multivoltine, of this species. The larvae and pupae were mainly collected from slow to moderately flowing stream with well-developed trailing grasses. Larvae were infrequently infected with unidentified microsporidian fungi (14 out of 215 larvae in a single stream).

#### *Striatum* species-group

*Striatum* species-group contains 23 species which are all recorded from Oriental and Palearctic region (Adler and Crosskey, 2015). Single species is known to occur in Korea.

#### *Simulium (Simulium) quinquestriatum* (Shiraki, 1935) (Figs. 21–23)

*Stilboplax 5-striatum* Shiraki, 1935: 27 (type localities: Kap-pansan, Shinchiku-Prefecture; Kanshirei, Arisan, Funkiko, Tainan-Prefecture; Suisha, Taichu-Prefecture, Taiwan).

*Simulium (Stilboplax) 5-striatum*: Ogata and Sasa, 1954: 331 (Japanese list); 1955a: 11 (Japanese key); Ogata and Sasa, 1955b: 40 (Japanese list); Ogata et al., 1956: 77 (Japanese species); Shogaki, 1956: 274 (Japanese list and taxonomy).

*Simulium griescens*, not Brunetti: Bentinck, 1955: 8 (Korean and Japanese species and key).

*Simulium 5-striatum*: Rubtsov, 1963b: 543 (taxonomy).

*Simulium (Simulium) 5-striatum*: Orii et al., 1969: 1–13 (Japanese key).

*Simulium quinquestriatum*: Chow, 1973: 45 (Korean list); Paek et al., 2010: 221 (Korean list); Takaoka et al., 2012: 374 (ecology).

*Simulium (Simulium) quinquestriatum*: Anonymus, 1974: 192 (Japanese list); Takaoka, 1977a: 205 (redescription); 1977b: 219 (Japanese key); 1979: 396 (redescription); Uemoto, 1985: 332 (Japanese key and taxonomy); 2005: 1018 (Japanese key and taxonomy); Yoon and Song, 1989: 43 (redescription); Crosskey and Howard, 2004: 68 (checklist); Kim, 2013: 101 (Korean checklist); Adler and Crosskey, 2015: 96 (checklist).

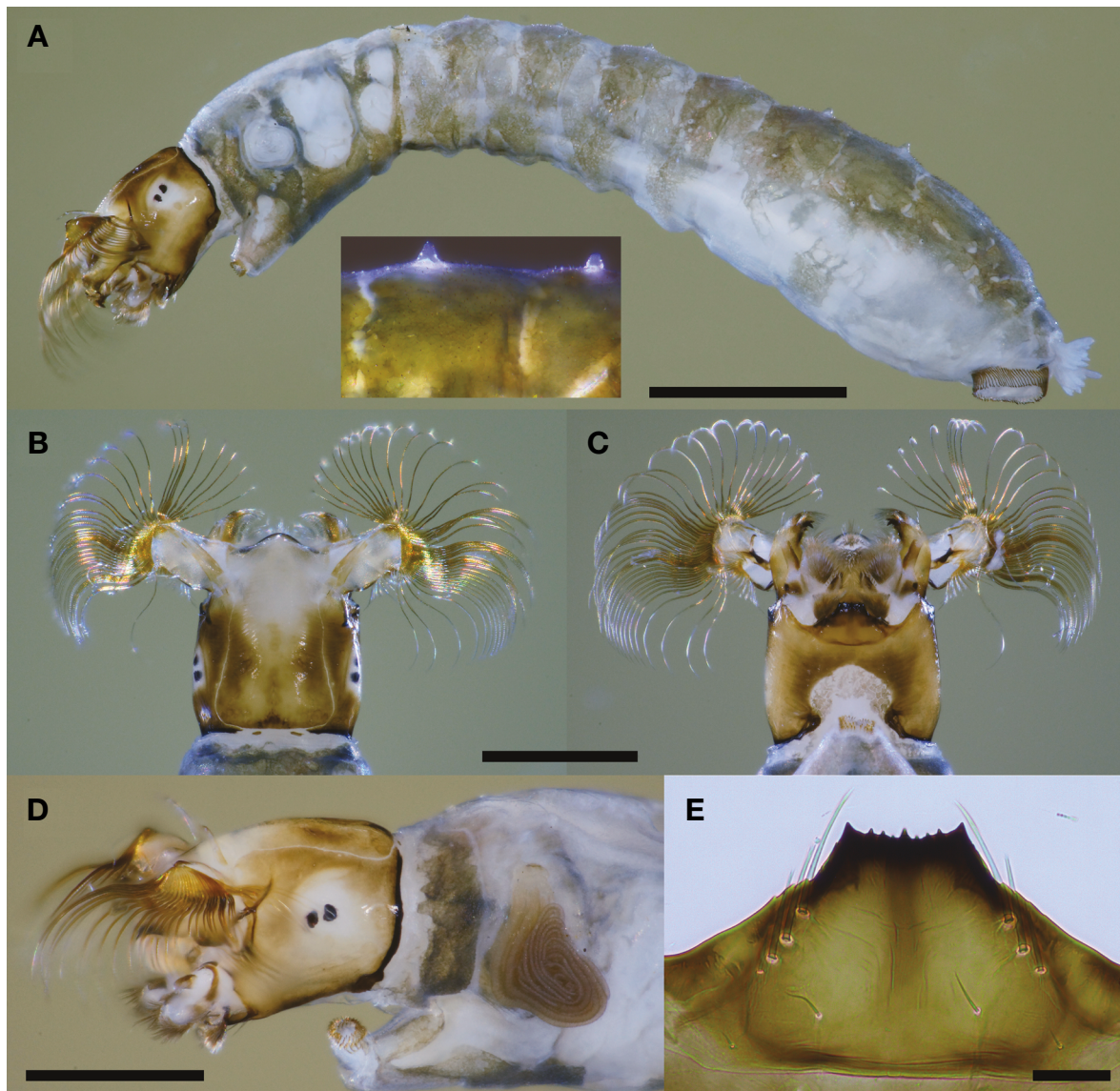
*Simulium (Striatosimulium) quinquestriatum*: Rubtsov and Yankovsky, 1988: 179 (Palearctic catalogue).

**Material examined.** Korea: Gangwon-do: Hongcheon-gun, Hwachon-myeon, Guseongpo-ri, 37°48'21"N, 127°54'29"E, 28 Jun 2010, Kim SK (39 ultimate/penultimate, 156 early instar larvae); Hongcheon-gun, Bukbang-myeon, Seongdong-ri, 37°44'46"N, 127°53'02"E, 28 Jun 2010, Kim SK (41 ultimate/penultimate, 43 early instar larvae; 22 pupae); Jeollanam-do: Damyang-gun, Nam-myeon, Jigok-ri, 35°10'55"N, 127°00'37"E, 31 Jul 2011, Kim SK (22 ultimate/penultimate, 163 early instar larvae; 3 pupae); Chungcheongbuk-do: Boeun-gun, Songnisan-myeon, Sanae-ri, 36°32'24"N, 127°49'52"E, 28 May 2012, Kim SK (30 ultimate/penultimate, 34 early instar larvae; 1 pupa).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon boot shaped, gill of 10 filaments; and larvae with miter shaped postgenal cleft, abdominal cuticle uniformly covered with minute setae and with prominent dorsal protuberances arranged in pair on each segment.

**Description.** Mature Larva (Fig. 21). Body length 5.0–5.9 mm ( $n = 20$ ). Body (Fig. 21A) greyish green or greyish green with reddish brown areas, each abdominal segment with paired prominent dorsal protuberances and short dark setae uniformly distributed (inset of Fig. 21A). Head capsule (Fig. 21B–D) yellowish brown ground color with dark brown areas; head spots positive, indistinctive; head spot areas yellowish brown, surrounding areas dark brown; anteromedial spots indistinctive; anterolateral spots adjacent. Antenna





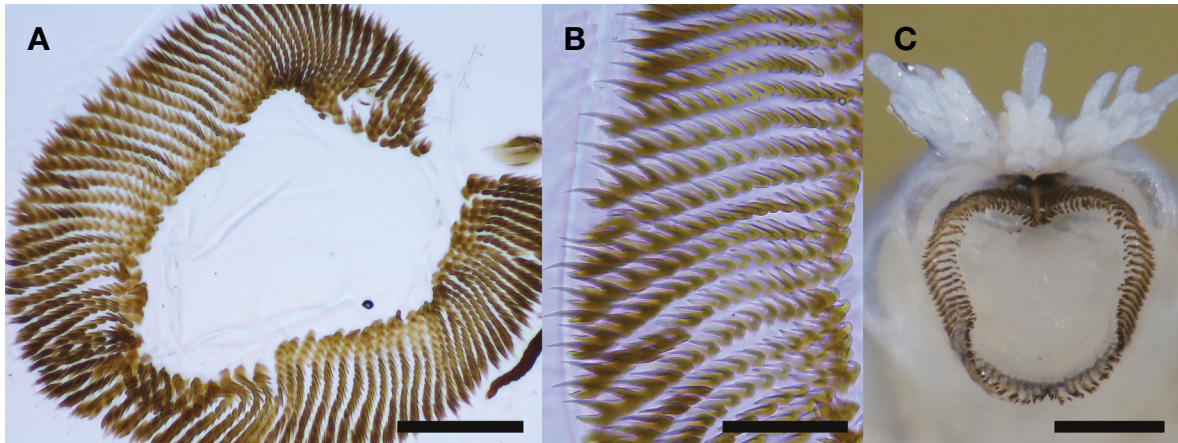
**Fig. 21.** *Simulium* (*Simulium*) *quinquestriatum*. A, Larva, lateral view (inset: thoracic protuberances); B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars = 1 mm (A), 0.5 mm (B–D), 50  $\mu$ m (E).

(Fig. 21B, D) yellowish brown, distal article brown, median article with hyaline band, extended beyond apex of labral fan stem by about 1/2 of distal article. Labral fan (Fig. 21B, C) with 35–41 primary rays. Postgenal cleft (Fig. 21C) large, miter shaped, wider than long, about 3.5–4 $\times$  as long as postgenal bridge, mottled with dark irregular spots; elongate lateral spot present. Lateral surface of head capsule (Fig. 21D) with 1–2 faint spots under ocelli. Gill histoblast with 10 filaments (Fig. 21D). Hypostoma (Fig. 21E) with 9 apical teeth; lateral teeth prominent, median tooth smaller than the lateral teeth; sublateral teeth small but distinct; paralateral

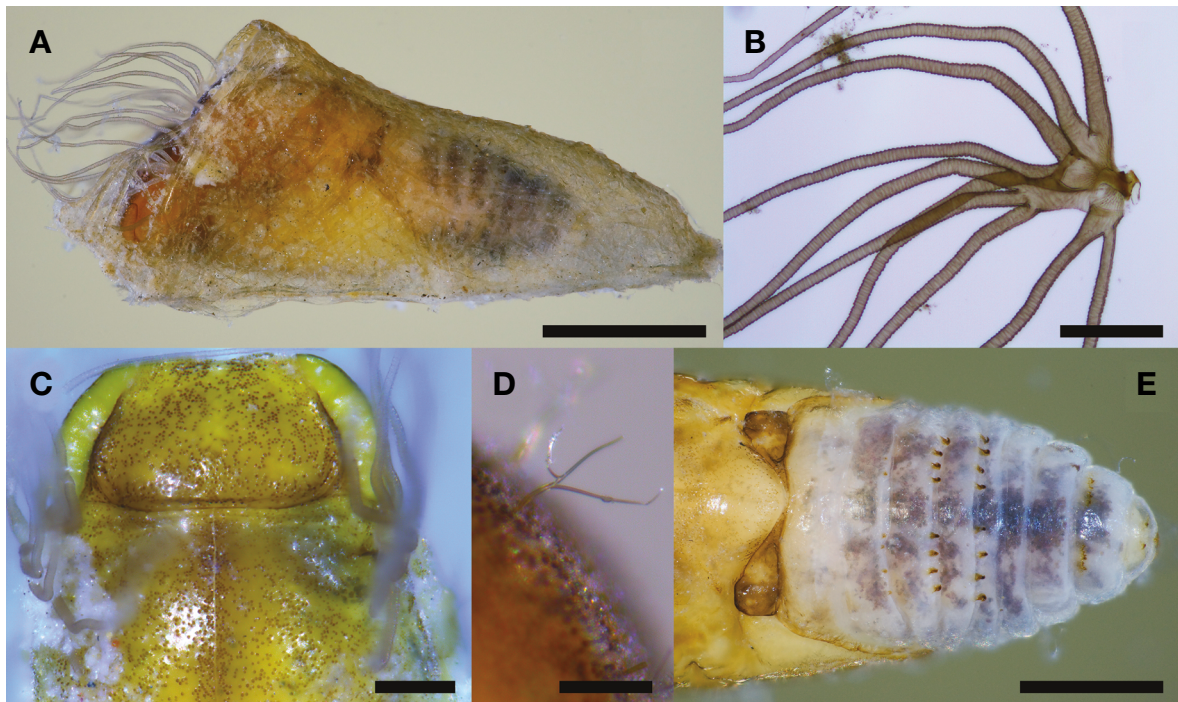
teeth not developed; lateral serrations weakly developed; hypostoma with 3–4 apically branched hypostomal setae. Posterior proleg (Fig. 22A, B) with 16–19 hooks in about 76–96 rows. Rectal papillae (Fig. 21C) of 3 lobes, each with 8–10 digit-like long secondary lobules.

Pupa (Fig. 23). Body length (excluding gill filaments) 2.1–2.8 mm ( $n = 10$ ). Cocoon (Fig. 23A) boot shaped, collar short, partly or completely embracing gill filaments, 3.1–3.9 mm long. Gill (Fig. 23B) with 10 filaments, 2 + (2 + 1) + (1 + 2) + 2 arrangement, ventral pair longer than other pairs; dorsalmost filament and ventralmost filament widely diver-





**Fig. 22.** *Simulium (Simulium) quinquestriatum*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, posterior view. Scale bars=0.1 mm (A), 50  $\mu$ m (B), 0.2 mm (C).



**Fig. 23.** *Simulium (Simulium) quinquestriatum*. A, Pupa and cocoon, lateral view; B, Gill filaments, phase-contrast micrograph; C, Pupal head and thorax, dorsal view; D, Pupal thoracic trichomes, lateral view; E, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.2 mm (B, C), 0.1 mm (D), 0.5 mm (E).

gent, angle between dorsalmost and ventralmost filaments about 180°. Cephalic plates and thorax (Fig. 23C) moderate to densely covered with relatively large tubercles. Frons with 2 short, simple trichomes; face with 1 short, simple trichome. Thoracic trichomes (Fig. 23D) in 6 pairs, long and branched (3 branched), about 2  $\times$  as long as cephalic

trichomes. Abdomen (Fig. 23E) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segments V–VII without spines; segment VIII with row of small spine combs; terminal hooks moderate to well developed.

**Distribution.** Korea, China, Japan, Taiwan, Thailand, Viet-

nam.

**Remarks.** This species is distinctive from other Korean black flies by having paired conical dorsal protuberances on each abdominal segments and uniformly distributed minute dark setae. This species is also unique in having 3-branched thoracic trichomes, compared to 4- to 7-branched trichomes in *S. japonicum*. Korean specimens agree well with the descriptions (Takaoka, 1977a, 1979) but slight differences need to be mentioned: body size (6.0–6.5 mm vs. 5.0–5.9 mm), number of primary rays (44 vs. 35–41), hooks on posterior proleg (18 hooks in 104 rows vs. 16–19 hooks in 76–96 rows). The larvae and pupae were mainly collected from slow to moderately flowing stream with well-developed trailing grasses or stream with relatively high content of organic matters. They were collected along with 9 other black flies. Relatively small numbers of pupa were collected during summer except single occasion (May to July). No natural enemy infected the larvae of this species observed in this study.

#### ***Tuberosum* species-group**

*Tuberosum* species-group contains 51 species plus 16 cytoforms from the world (Adler and Crosskey, 2015). Two species are known to occur in Korea.

#### ***Simulium (Simulium) rufibasis* Brunetti, 1911**

(Figs. 24–26)

*Simulium rufibasis* Brunetti, 1911: 285 (type locality: India, Kurseong, Darjeeling).

*Simulium (Simulium) rufibasis*: Puri, 1932: 899 (redescription); Ogata and Sasa, 1954: 332 (Japanese list); 1955a: 10 (Japanese key); Ogata et al., 1956: 94 (taxonomy and ecology); Datta and Pal, 1975: 160 (Indian key); Takaoka, 1977a: 213 (redescription); 1979: 395 (morphology and ecological note); 1989: 255 (collection record and morphological note); Uemoto, 1985: 332 (Japanese key and taxonomy); 2005: 1033 (Japanese key and taxonomy); Yoon and Song, 1989: 46 (redescription); Datta, 1992: 54 (morphological notes); Crosskey and Howard, 2004: 69 (checklist); Takaoka and Choochote, 2005: 110 (morphological note); Tangkawanit et al., 2009: 298 (cytotaxonomy); Kim, 2013: 101 (Korean checklist); Adler and Crosskey, 2015: 98 (checklist).

*Simulium yokotense* Shiraki, 1935: 74 (type locality: Yokote, Shimane-Prefecture, Japan).

*Simulium* sp. J-5: Bentinck, 1955: 9 (Korean and Japanese species and key).

*Simulium rufibasis*: Rubtsov, 1963b: 554 (redescription); Chow, 1973: 44 (Korean list); Ono, 1982: 300 (Japanese key and taxonomy); Sasaki et al., 1988: 87 (ecology); Baba and Takaoka, 1989: 307 (ecology); Paek et al., 2010: 221

(Korean list); Takaoka et al., 2012: 374 (ecology).

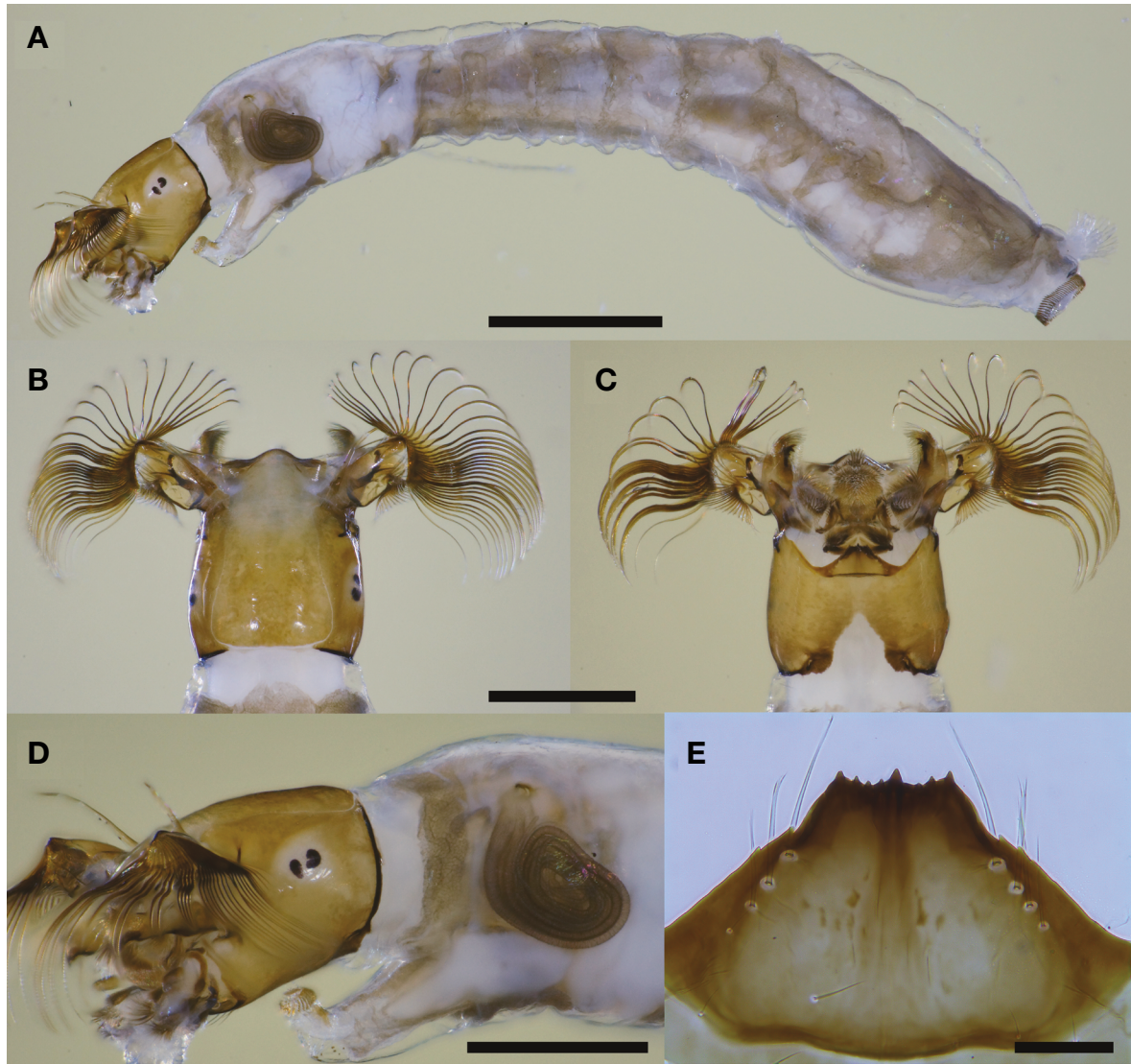
*Simulium (Archesimulium) rufibasis*: Rubtsov and Yankovsky, 1988: 179 (Palearctic catalogue).

**Material examined.** Korea: Gangwon-do: Chuncheon-si, Seo-myeon, Oweol-ri, 37°57'56"N, 127°37'26"E, 6 Jun 2010, Kim SK (204 ultimate/penultimate, 81 early instar larvae; 42 pupae); Gyeonggi-do: Gapyeong-gun, Buk-myeon, Hwaak-ri, 37°57'06"N, 127°34'41"E, 22 Jun 2010, Kim SK (13 ultimate/penultimate, 8 early instar larvae; 13 pupae); ditto, Hwaak-ri, 37°56'38"N, 127°32'20"E, 22 Jun 2010, Kim SK (10 ultimate/penultimate, 5 early instar larvae; 4 pupae); Gangwon-do: Chuncheon-si, Dongsan-myeon, Bongmyeong-ri, KNU experimental forest, 37°46'26"N, 127°48'46"E, 19 May 2012, Kim SK (133 ultimate/penultimate, 148 early instar larvae; 1 pupa); Jeollanam-do: Juk-gok-myeon, Namyang-ri, Mt. Cheondeoksan, 35°10'50"N, 127°20'30"E, 7 Sep 2012, Kim SK (76 ultimate/penultimate, 7 early instar larvae; 74 pupae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon slipper shaped, gill of 6 filaments, angle between dorsalmost and ventralmost filaments less than 90°, head with frontal trichomes long, terminal hooks not developed; and larvae with pointed bullet shaped postgenal cleft, head spots indistinctive, seemingly negative.

**Description.** Mature Larva (Fig. 24). Body length 5.5–6.0 mm (n = 20). Body (Fig. 24A) greenish grey to greyish brown. Head capsule (Fig. 24B–D) light brown to yellowish brown ground color; largely brown in some cases; head spots indistinctive, seemingly negative due to relatively dark surrounding areas; anteromedial spots positive, indistinctive; anterolateral and posterolateral spots seemingly negative; posteromedial spots positive. Antenna (Fig. 24B, D) light brown, distal article brown, median article with hyaline band, extended beyond apex of labral fan stem by about 1/2 of distal article. Labral fan (Fig. 24B, C) with 33–38 primary rays. Postgenal cleft (Fig. 24C) deep, pointed bullet shaped or conical shaped, laterally parallel-sided, 1.2–1.4 × as long as wide, about 1.7–2 × as long as postgenal bridge; distinct elongate lateral spot present, seemingly negative due to dark surrounding areas. Lateral surface of head capsule (Fig. 24D) without spots under ocelli. Gill histoblast with 6 filaments (Fig. 24D). Hypostoma (Fig. 24E) with 9 apical teeth; median tooth prominent, lateral teeth as long as median tooth; sublateral teeth small, well developed; paralateral teeth not developed; 3–4 lateral serrations moderately developed; hypostoma with 3–4 apically branched hypostomal setae. Posterior proleg (Fig. 25A, B) with 11–14 hooks in about 72–76 rows. Rectal papillae (Fig. 25C) of 3 lobes, each with 8–11 digit-like long secondary lobules.





**Fig. 24.** *Simulium* (*Simulium*) *rufibasis*. A, Larva, lateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars=1 mm (A), 0.5 mm (B–D), 50  $\mu$ m (E).

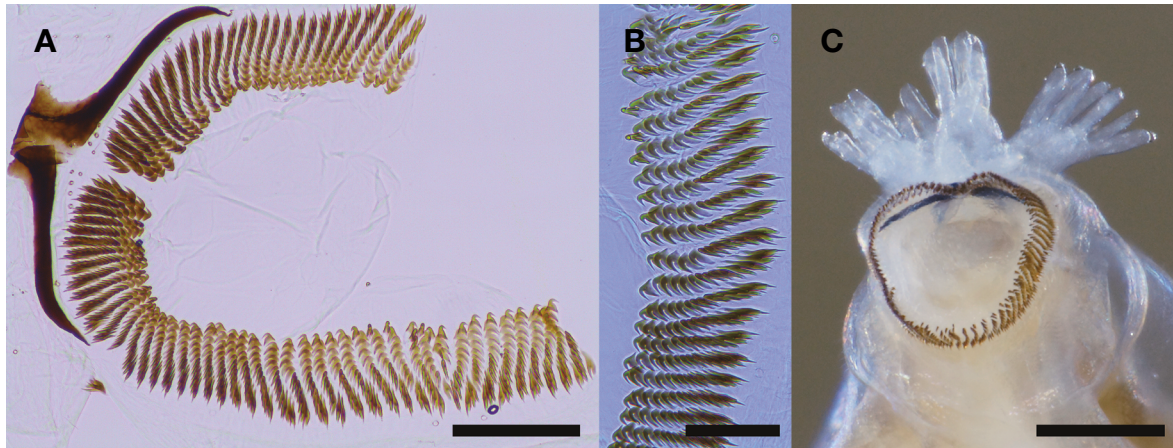
Pupa (Fig. 26). Body length (excluding gill filaments) 2.6–3.3 mm ( $n=20$ ). Cocoon (Fig. 26A) slipper shaped, usually base of gill exposed in lateral view, 2.9–3.2 mm long. Gill (Fig. 26A, B) with 6 filaments, 2 + 2 + 2 arrangement, each pair with short stalk, dorsalmost filament and ventralmost filament not divergent, angle between dorsalmost and ventralmost filaments less than  $90^\circ$ . Cephalic plates and thorax (Fig. 26C) moderate to densely covered with small tubercles. Frons with 2 distinctive long, simple trichomes (Fig. 26C); face with 1 long, simple trichome, as long as or little shorter than frontal trichomes. Thoracic trichomes (Fig. 26B) in 6 pairs, long and simple, about  $1.4\times$  as long as

cephalic trichomes. Abdomen (Fig. 26D) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segments V–VI without spines; segments VII–IX with row of small spine combs; terminal hooks not developed.

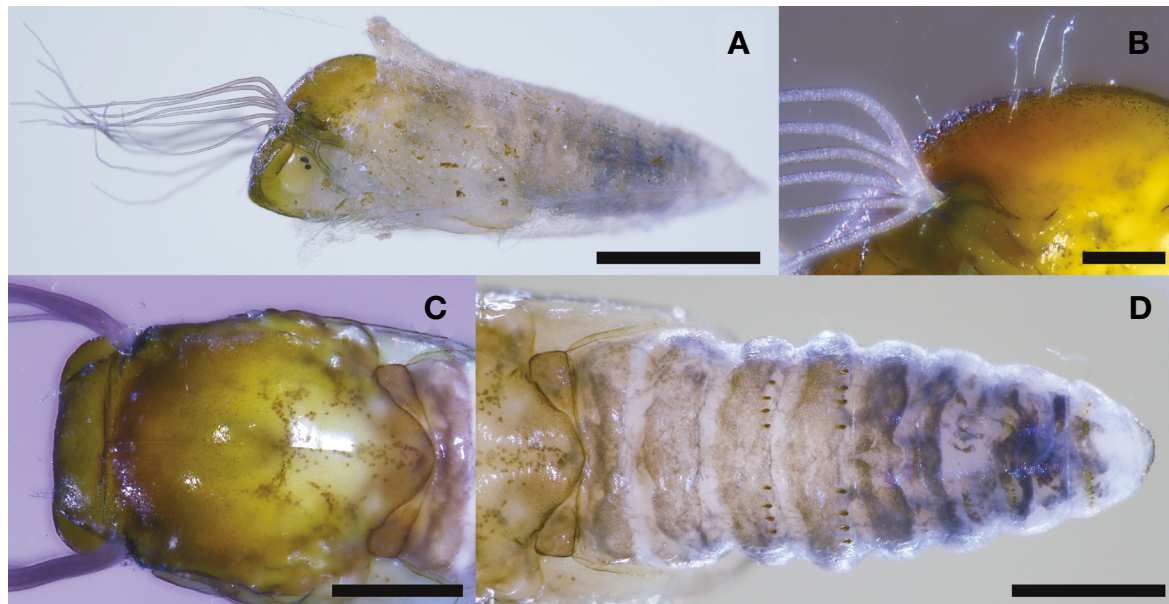
**Distribution.** Korea, Myanmar, China, India, Japan, Nepal, Pakistan, Taiwan, Thailand, Vietnam.

**Remarks.** This species is known to feed blood from bird, horse, and human (Sasaki et al., 1988). Nine larval instars were identified for this species based on the measurements of head capsules of laboratory-reared individuals (Baba and Takaoka, 1989). The identity of this species is not clearly





**Fig. 25.** *Simulium (Simulium) rufibasis*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, postero-ventral view. Scale bars=0.1 mm (A), 50 µm (B), 0.2 mm (C).



**Fig. 26.** *Simulium (Simulium) rufibasis*. A, Pupa and cocoon, lateral view; B, Pupal thorax and gill filaments, lateral view; C, Pupal head and thorax, dorsal view; D, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.2 mm (B), 0.5 mm (C, D).

understood. Chromosomal analysis indicated that Japanese species known as *S. rufibasis* might be misidentification of *Simulium vulgare* (Peter H. Adler, personal communication). Korean *S. rufibasis* might also be a misidentification of *S. vulgare* as in Japanese species. However immatures of Korean species are morphologically similar to a species from Thailand, *Simulium doipuiense*, rendering temporally identified as “*Simulium rufibasis/doipuiense*” (Peter H. Adler, personal information). Takaoka and Choochote (2005) indicated that *S. doipuiense* can be distinguished from *S.*

*rufibasis* by lacking terminal hooks in pupal abdomen. However *S. rufibasis* is also clearly lacking terminal hooks in pupal abdomen, making it indistinguishable from each other. Chromosomal banding patterns can be used to separate these morphologically similar species (Tangkawanit et al., 2009). This species is morphologically similar to *Simulium (Simulium) suzukii* in many aspects, but can be distinguished from the latter by the following morphological differences; larvae without banding patterns on abdomen, pupal head with frontal trichomes noticeably long, lacking



terminal hooks, and gill with all filaments with short stalks. The larvae and pupae were mainly collected from moderate to fast flowing streams with well-developed trailing grasses, leaves, and twigs. Large numbers were collected from trailing grasses, leaves and twigs in forest stream. Larvae were infrequently infected with unidentified microsporidian fungi and *Coelomycidium simulii* fungus. They were most frequently collected with *S. suzukii*.

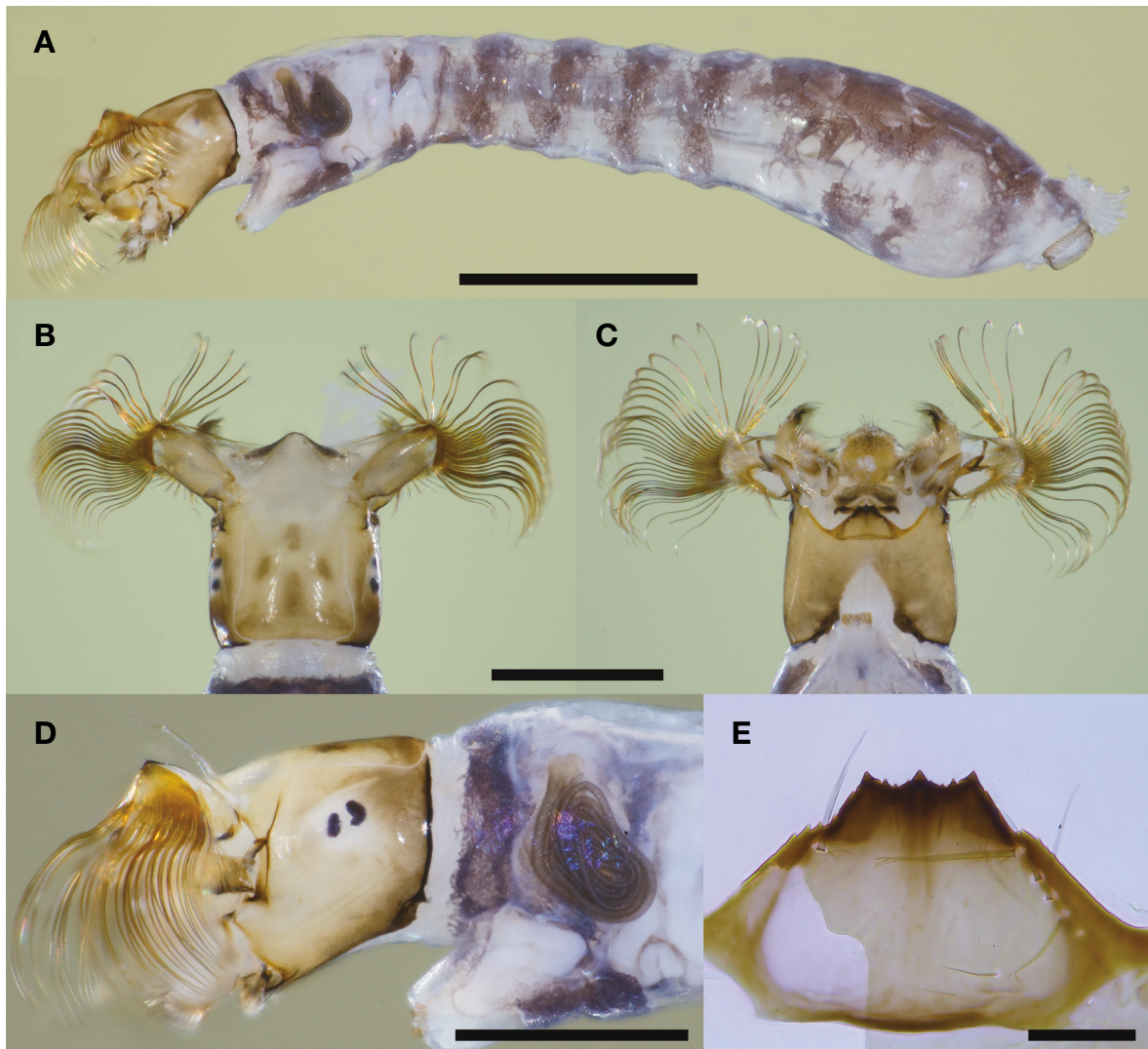
***Simulium (Simulium) suzukii* Rubtsov, 1963  
(species complex) (Figs. 27–29)**

*Simulium suzukii* Rubtsov, 1963a: 525 (type locality: “Japania”).

*Simulium ryukyuense* Ogata, 1966: 123 (type locality: Yona, Okinawa, Japan); Anonymus, 1974: 192 (Japanese list).

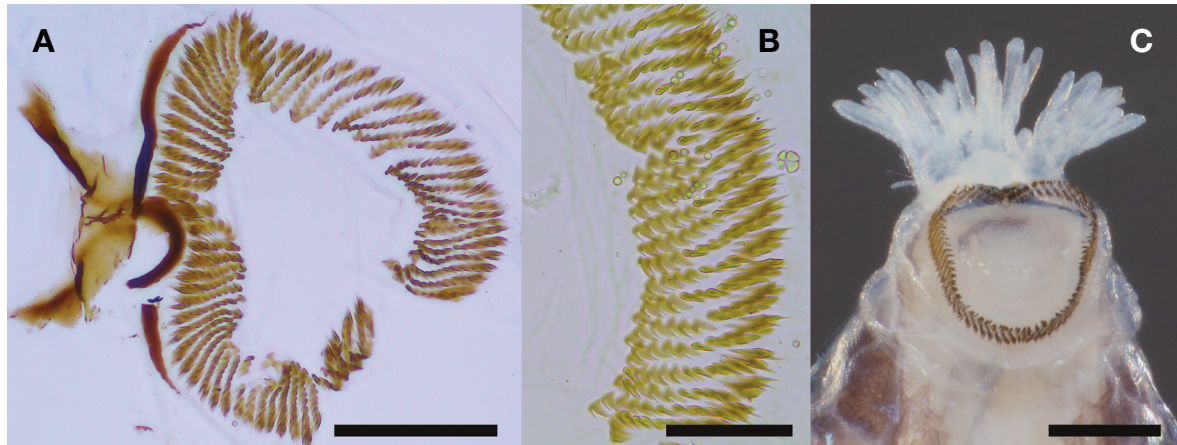
*Simulium (Simulium) suzukii*: Orii et al., 1969: 1–13 (Japanese key); Anonymus, 1974: 192 (Japanese list); Takaoka, 1977a: 209 (redescription); 1977b: 219 (Japanese key); 1979: 395 (morphology and ecological note); Uemoto, 1985: 332 (Japanese key and taxonomy); 2005: 1018 (Japanese key and taxonomy); Yoon and Song, 1989: 47 (redescription); Crosskey and Howard, 2004: 69 (checklist); Kim, 2013: 101 (Korean checklist); Adler and Crosskey, 2015: 98 (checklist).

*Simulium suzukii*: Chow, 1973: 45 (Korean list); Ono, 1982: 300 (Japanese key and taxonomy); Paek et al., 2010: 221

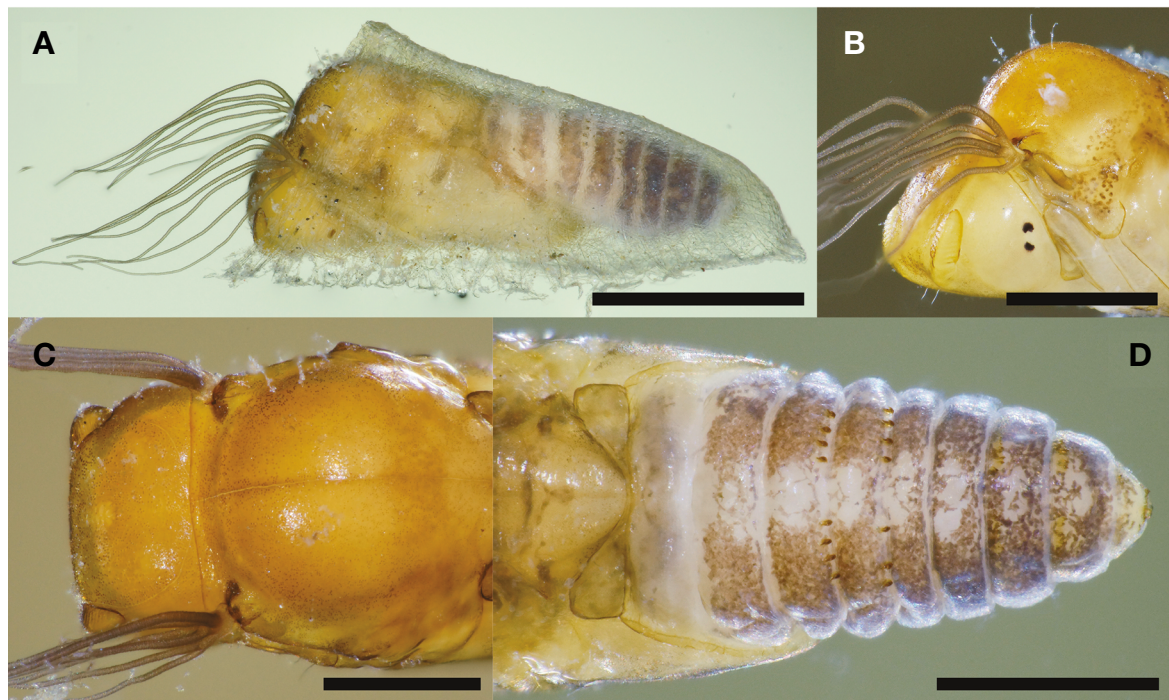


**Fig. 27.** *Simulium (Simulium) suzukii*. A, Larva, lateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars=1 mm (A), 0.5 mm (B–D), 50  $\mu$ m (E).





**Fig. 28.** *Simulium (Simulium) suzukii*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, posteroven-tral view. Scale bars=0.1 mm (A), 50  $\mu$ m (B), 0.2 mm (C).



**Fig. 29.** *Simulium (Simulium) suzukii*. A, Pupa and cocoon, lateral view; B, Pupal head and thorax with gill filaments, anterolateral view; C, Pupal head and thorax, dorsal view; D, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.5 mm (B–D).

(Korean list); Adler et al., 2013: 1 (cytotaxonomy and phylogeny).

*Simulium (Simulium) tuberosum*, not Lundstrom: Anonymus, 1965: 192 (redescription in Japanese); Ogata and Sasa, 1954: 332 (Japanese list); Ogata and Sasa, 1955a: 11 (Japanese list and key); Ogata and Sasa, 1955b: 41 (Japanese list); Bentinck, 1955: 9 (Korean and Japanese species and

key); Ogata et al., 1956: 93; Shogaki, 1956: 275 (Japanese list and taxonomy).

*Simulium (Archesimulium) suzuki* [sic]: Rubtsov and Yankovsky, 1988: 179 (Palearctic catalogue).

‘J’ Tangkawanit, Kuvangkadilok, Baimai & Adler, 2009 (*tani* cytoform)

‘A’ Adler, Huang, Reeves, Kim, Otsuka & Takaoka, 2013

(cytoform)

‘B’ Adler, Huang, Reeves, Kim, Otsuka & Takaoka, 2013  
(cytoform)

‘C’ Adler, Huang, Reeves, Kim, Otsuka & Takaoka, 2013  
(cytoform)

‘D’ Adler, Huang, Reeves, Kim, Otsuka & Takaoka, 2013  
(cytoform)

**Material examined.** Korea: Gangwon-do: Hongcheon-gun, Bukbang-myeon, Wonso-ri, 37°42′08″N, 127°43′30″E, 10 Jun 2010, Kim SK (100 ultimate/penultimate, 73 early instar larvae; 83 pupae); Chuncheon-si, Namsan-myeon, Banghari, 37°47′19″N, 127°32′42″E, 20 Jun 2010, Kim SK (160 ultimate/penultimate, 47 early instar larvae; 61 pupae); Gyeonggi-do: Gapyeong-gun, Buk-myeon, Hwaak-ri, 37°57′06″N, 127°34′41″E, 22 Jun 2010, Kim SK (116 ultimate/penultimate, 97 early instar larvae; 34 pupae); ditto, Hwaak-ri, 37°56′38″N, 127°32′20″E, 22 Jun 2010, Kim SK (90 ultimate/penultimate, 12 early instar larvae; 19 pupae); Jeollanam-do: Jukgok-myeon, Namyang-ri, Mt. Cheondeoksan, 35°10′50″N, 127°20′30″E, 7 Sep 2012, Kim SK (145 ultimate/penultimate, 12 early instar larvae; 141 pupae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon slipper shaped, gill of 6 filaments, angle between dorsalmost and ventralmost filaments about 90°, head with frontal trichomes short, terminal hooks moderately developed; and larvae with bullet shaped postgenal cleft, head spots positive, distinctive, abdominal segments with banding patterns.

**Description.** Mature Larva (Fig. 27). Body length 4.1–4.7 mm (n = 20). Body (Fig. 27A) pale with greyish brown to light brown patterns. Head capsule (Fig. 27B–D) pale to brownish yellow ground color with brown areas; head spots positive, distinctive, sometimes seemingly negative due to dark surrounding areas; anteromedial spots positive; anterolateral spots fused; posterolateral spots seemingly negative. Antenna (Fig. 27B, D) pale, distal article light brown, extended beyond apex of labral fan stem by about 1/2 of distal article. Labral fan (Fig. 27B, C) with 34–36 primary rays. Postgenal cleft (Fig. 27C) deep, pointed bullet shaped or spearhead shaped, about 1.2 × as long as wide, about 2–3.5 × as long as postgenal bridge; distinct elongate lateral spot present, seemingly negative due to relatively dark surrounding areas. Lateral surface of head capsule (Fig. 27D) with single spot under ocelli. Gill histoblast with 6 filaments (Fig. 27D). Hypostoma (Fig. 27E) with 9 apical teeth; median tooth prominent, lateral teeth as long as median tooth; sublateral teeth small; paralateral teeth weakly developed; 3–4 lateral serrations well developed; hypostoma with 4–5 apically branched hypostomal setae. Posterior proleg

(Fig. 28A, B) with 10–12 hooks in about 68–72 rows. Rectal papillae (Fig. 28C) of 3 lobes, each with 7–10 digit-like long secondary lobules.

Pupa (Fig. 29). Body length (excluding gill filaments) 1.9–2.4 mm (n = 20). Cocoon (Fig. 29A) slipper shaped, 2.3–2.7 mm long. Gill (Fig. 29A, B) with 6 filaments, 2 + 2 + 2 arrangement, stalk of ventral pair longer than the others, dorsalmost filament and ventralmost filament not widely divergent, angle between dorsalmost and ventralmost filaments about 90°. Cephalic plates and thorax (Fig. 29B, C) moderate to densely covered with small tubercles. Frons with 2 short, simple trichomes; face with 1 short, simple trichome (Fig. 29B). Thoracic trichomes (Fig. 29B) in 6 pairs, long and simple, about 1.5–1.7 × as long as cephalic trichomes. Abdomen (Fig. 29D) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segments V–VI without spines; segments VII–IX with row of small spine combs; terminal hooks moderately developed.

**Distribution.** Korea, China, Japan, Siberia.

**Remarks.** This species has been considered as a good biological species but recent finding indicates that *S. (S.) suzukii* may be a species complex including at least 5 distinct cytoforms (Adler et al., 2013; Adler and Crosskey, 2015). Two cytoforms, “A” and “B”, are known to occur in Korea. Both cytoforms are recorded from the same locality (Chuncheon-si, Namsan-myeon, Banghari) indicating reproductive isolation between them (Adler et al., 2013). All the previous records of Japanese “*tuberosum*” are misidentification of *Simulium (Simulium) suzukii*. The larvae and pupae were commonly collected from various streams. Large numbers were collected from trailing grasses, leaves and twigs in fast flowing streams. Larvae were infrequently infected with unidentified microsporidian fungi, mermithid nematodes and *Coelomycidium simulii* fungus.

#### *Variegatum* species-group

*Variegatum* species-group contains 56 species from the world (Adler and Crosskey, 2015). Single species is known to occur in Korea.

#### *Simulium (Simulium) oitanum* (Shiraki, 1935)

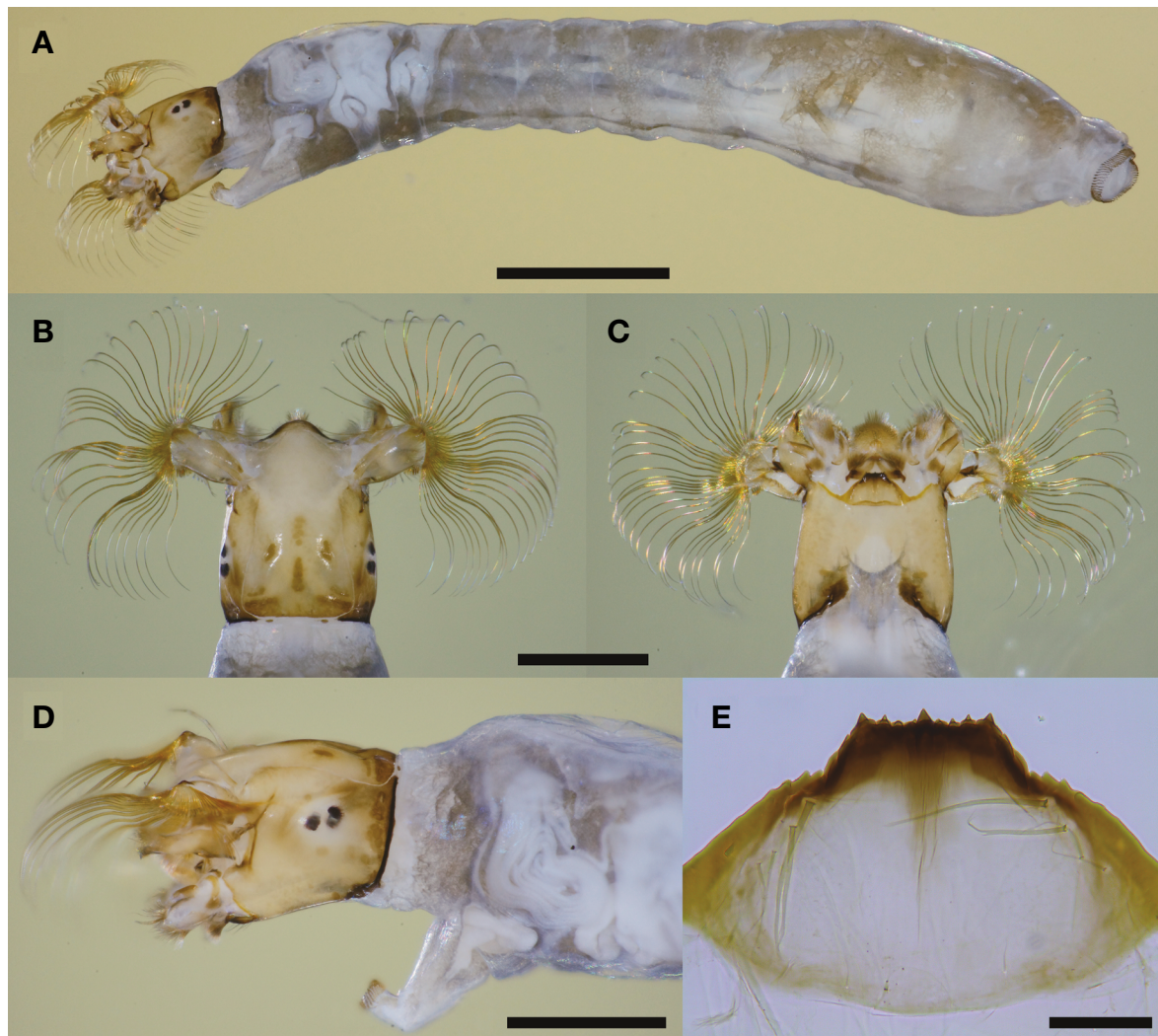
(Figs. 30–32)

*Odagmia oitana* Shiraki, 1935: 37 (type locality: Oita, Japan).

*Odagmia aokii* Takahasi, 1941: 86 (type locality: Tuyutani, Tottori, Japan); Ono, 1982: 295 (Japanese key and taxonomy).

*Simulium (Simulium) oitanum*: Crosskey and Howard, 2004: 71 (checklist); Kim, 2013: 101 (Korean checklist); Adler and Crosskey, 2015: 101 (checklist).





**Fig. 30.** *Simulium (Simulium) oitanum*. A, Larva, ventrolateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars = 1 mm (A), 0.5 mm (B–D), 50 µm (E).

*Odgmia oitana*: Rubtsov and Yankovsky, 1988: 168 (Palearctic catalogue).

*Simulium oitana*: Bentinck, 1955: 10 (Korean and Japanese species and key).

*Simulium (Odgmia) oitanum*: Ogata and Sasa, 1954: 331 (Japanese list); Anonymus, 1974: 192 (Japanese list); Uemoto, 1985: 331 (Japanese key and taxonomy); 2005: 1018 (Japanese key and taxonomy).

*Simulium aokii*: Ogata, 1954: 100 (ecology); Chow, 1973: 44 (Korean list); Paek et al., 2010: 221 (Korean list).

*Odgmia aokii*: Rubtsov and Yankovsky, 1988: 163 (Palearctic catalogue).

*Simulium (Odgmia) aokii*: Ogata and Sasa, 1954: 331 (Japanese list); Takahasi, 1959: 635 (redescription); Anony-

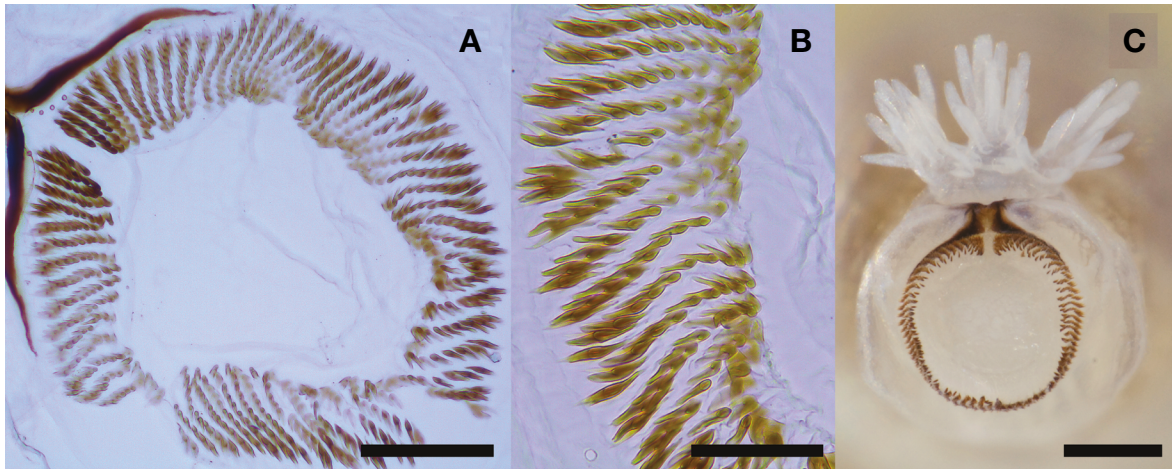
mus, 1965: 191 (redescription in Japanese); Anonymus, 1974: 192 (Japanese list); Takaoka, 1976: 390 (redescription); 1977b: 219 (Japanese key); Uemoto, 1985: 331 (Japanese key and taxonomy).

*Simulium (Simulium) aokii*: Yoon and Song, 1989: 40 (redescription).

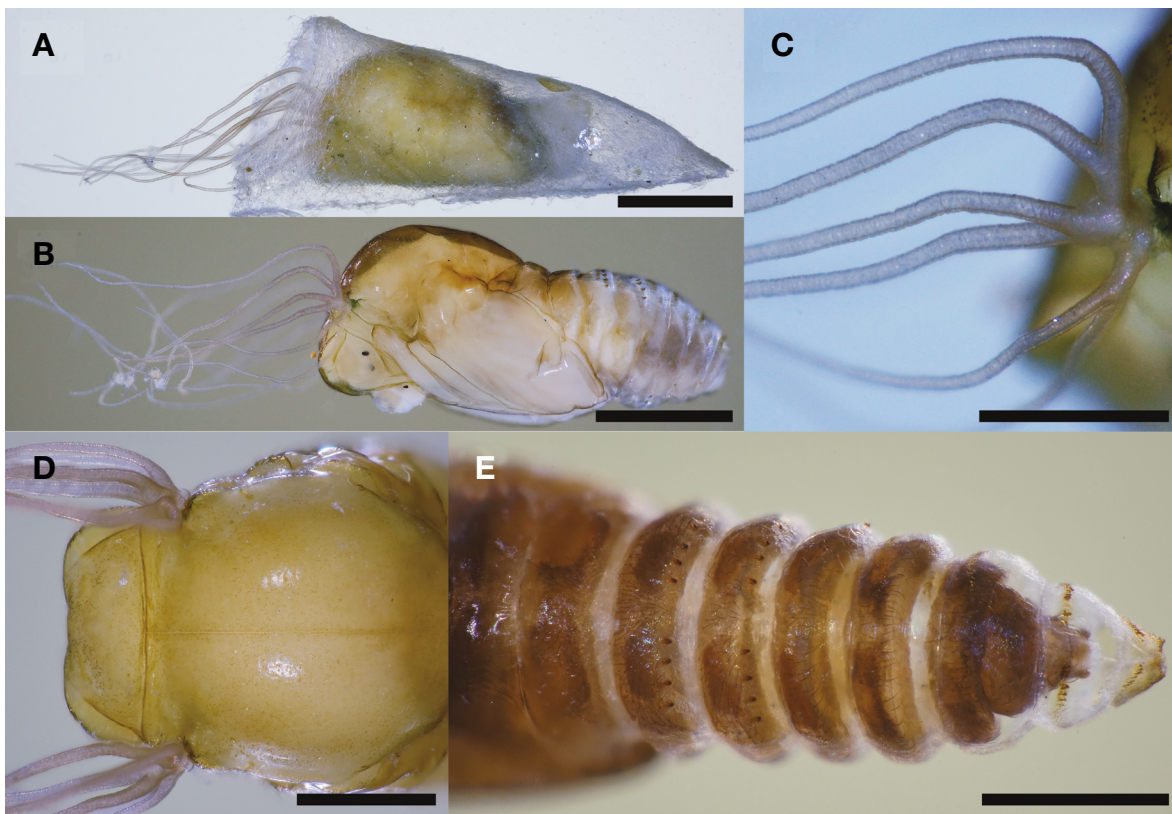
*Simulium oitanum*: Takaoka et al., 2012: 374 (ecology).

**Material examined.** Korea: Gangwon-do: Chuncheon-si, Seo-myeon, Bangdong-ri, 37°53'45"N, 127°40'49"E, 10 Nov 2009, Kim SK (2 pupae); ditto, Namsan-myeon, Sudong-ri, 37°46'38"N, 127°39'38"E, 22 May 2010, Kim SK (8 ultimate/penultimate instar larvae; 6 pupae); Gyeonggi-do: Gapyeong-gun, Buk-myeon, Hwaak-ri, 37°57'06"N, 127°





**Fig. 31.** *Simulium* (*Simulium*) *oitanum*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, posterior view. Scale bars=0.1 mm (A), 50  $\mu$ m (B), 0.2 mm (C).



**Fig. 32.** *Simulium* (*Simulium*) *oitanum*. A, Pupa and cocoon, lateral view; B, Pupa, lateral view; C, Gill filaments, lateral view; D, Pupal head and thorax, dorsal view; E, Pupal abdomen, dorsal view. Scale bars=1 mm (A, B), 0.5 mm (C-E).

34°41'E, 22 Jun 2010, Kim SK (12 ultimate/penultimate, 7 early instar larvae; 12 pupae); ditto, Dodae-ri, Gapyeongcheon stream, 37°57'26"N, 127°28'22"E, 26 May 2011, Kim

SK (1 ultimate/penultimate, 1 early instar larvae); Gangwon-do: Inje-gun, Girin-myeon, Jindong-ri, Sangjicheon stream, 37°49'25"N, 128°23'35"E, 2 Jul 2011, Kim SK (33 ultimate/

penultimate, 3 early instar larvae; 5 pupae); Chuncheon-si, Dongsan-myeon, Bongmyeong-ri, KNU experimental forest, 37°46'26"N, 127°48'46"E, 19 May 2012, Kim SK (21 ultimate/penultimate, 42 early instar larvae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon slipper shaped, gill of 6 filaments, widely divergent, angle between dorsalmost and ventralmost filaments well over 100°, pupal abdominal tergite 6 with spine comb; and larvae with large ovate shaped postgenal cleft, not pointed, head spots distinct, positive.

**Description.** Mature Larva (Fig. 30). Body length 5.7–6.7 mm (n = 10). Body (Fig. 30A) greyish brown ground color. Head capsule (Fig. 30B–D) yellowish brown; all head spots distinct, positive; anteromedial spots separated; anterolateral spots fused; 1st and 2nd posterolateral spots separated. Antenna (Fig. 30B, D) pale to yellowish brown, distal article brown, extended beyond apex of labral fan stem by about 1/2 of distal article. Labral fan (Fig. 30B, C) with 35–40 primary rays. Postgenal cleft (Fig. 30C) deep, ovate shaped, not sharply pointed, about as long as wide, about 1.6–2 × as long as postgenal bridge; distinct elongate lateral spot present, brown; subesophageal ganglion darkly pigmented. Lateral surface of head capsule (Fig. 30D) 3 distinct spots under ocelli. Hypostoma (Fig. 30E) with 9 apical teeth; median tooth prominent, lateral teeth little shorter than median tooth; sublateral teeth small but well developed; 1–2 paralaral teeth weakly developed; 3–4 lateral serrations well developed; hypostoma with 3–4 apically branched hypostomal setae. Gill histoblast with 6 filaments (Fig. 30D). Posterior proleg (Fig. 31A, B) with 10–11 hooks in about 76–82 rows. Rectal papillae (Fig. 31C) of 3 lobes, each with 7–10 digit-like long secondary lobules.

Pupa (Fig. 32). Body length (excluding gill filaments) 2.7–3.3 mm (n = 10). Cocoon (Fig. 32A) slipper shaped, enclosing base of gill filaments, 3.7–4.6 mm long. Gill (Fig. 32B, C) with 6 filaments, 2 + 2 + 2 arrangement, stalk of ventral pair longer than the others, dorsalmost filament and ventralmost filament divergent, angle between dorsalmost and ventralmost filaments well over 100°; dorsalmost filament directed upwardly than forwardly, making right angle. Cephalic plates and thorax (Fig. 32D) moderately covered with small tubercles. Frons with 2 short, simple trichomes; face with 1 short, simple trichome. Thoracic trichomes in 6 pairs, short and simple, about 1.5 × as long as cephalic trichomes. Abdomen (Fig. 32D) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segment V without spines; segments VI with minute spine comb, sometimes indistinct; segment VII–IX with row of small spine combs; terminal hooks moderately developed.

**Distribution.** Korea, China, Japan, Nepal, Siberia.

**Remarks.** This species is among the most common black flies in Japan which attack human seriously (Ogata, 1954). Morphological features of Korean specimens differed slightly from Japanese species described by Takaoka (1976, as *Simulium* (*Odagmia*) *aokii*) in number of secondary lobules of rectal papillae (1–3 short finger-like lobules in Japanese specimens) and larval body size (6.3–7.0 mm in Japanese specimens). Previous work showed that Korean specimens (Yoon and Song, 1989) have much smaller body length (4.4–4.8 mm) compared to Japanese specimens and specimens used in this study. The larvae and pupae of this species were not commonly encountered but sporadically collected from mostly northern part of Korea. Immatures were primarily collected from moderate to fast flowing streams with well-developed trailing grasses.

#### *Venustum* species-group

*Venustum* species-group contains 36 species from the world (Adler and Crosskey, 2015). Single species is known to occur in Korea.

#### *Simulium* (*Simulium*) *arakawae* Matsumura, 1915 (Figs. 33–35)

*Simulium arakawae* Matsumura, 1915: 85 (type locality: Sapporo, Hokkaido, Japan).

*Simulium arakawae*: Takahasi, 1950: 1559 (Japanese list); Bentinck, 1955: 9 (Korean and Japanese species and key); Rubtsov, 1963b: 558 (taxonomy); Chow, 1973: 44 (Korean list); Ono, 1977: 266 (redescription); Paek et al., 2010: 221 (Korean list); Huang et al., 2011: 376 (cytotaxonomy); Takaoka et al., 2012: 374 (ecology).

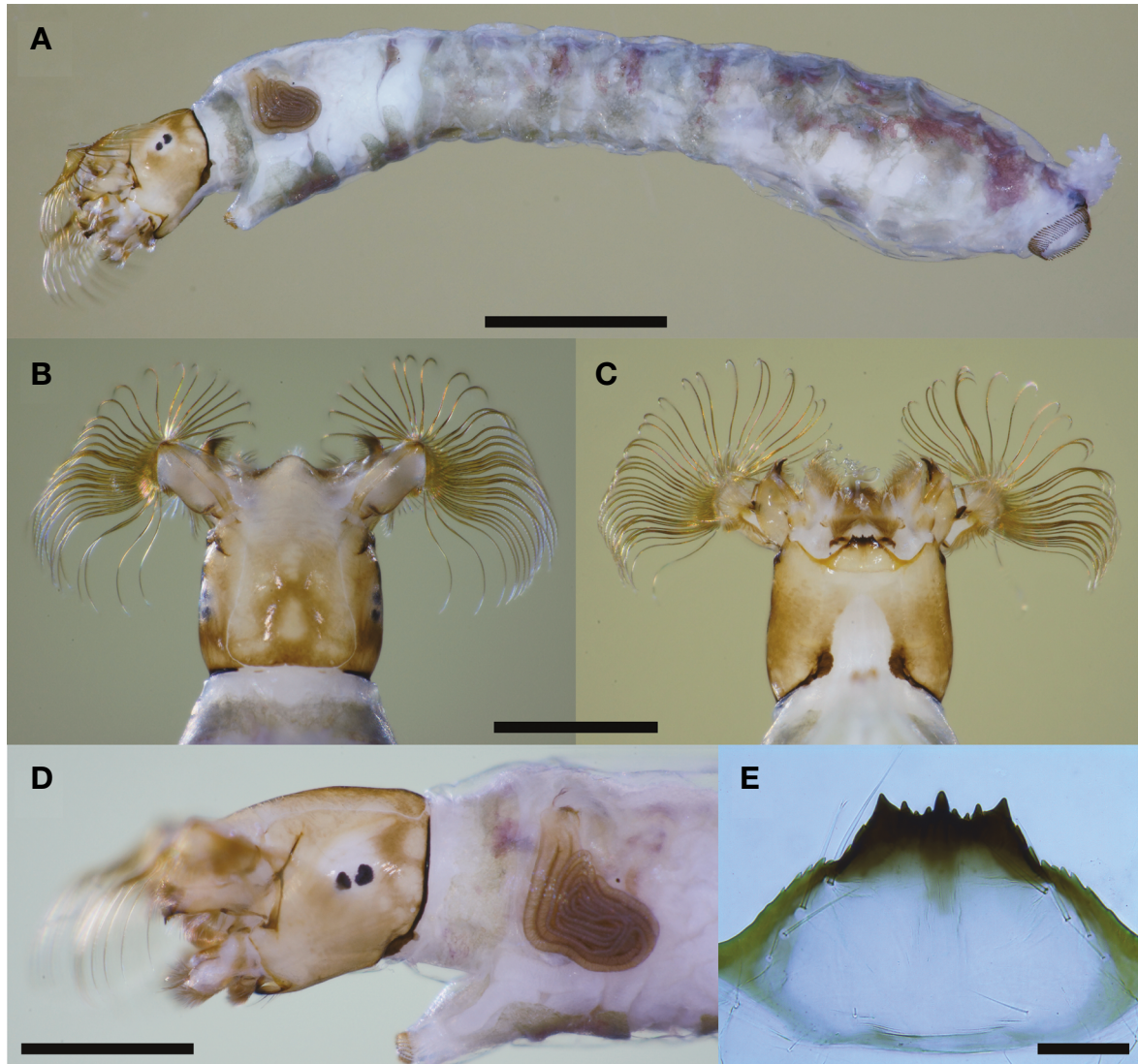
*Simulium* (*Simulium*) *arakawae*: Shogaki, 1956: 276 (Japanese list and taxonomy); Orii et al., 1969: 1–13 (Japanese key); Takaoka, 1977a: 193 (redescription); 1977b: 219–224 (Japanese key); Uemoto, 1985: 332 (Japanese key and taxonomy); 2005: 1018 (Japanese key and taxonomy); Rubtsov and Yankovsky, 1988 (Palearctic catalogue); Takaoka and Okazawa, 1988: 101 (Japanese list); Yoon and Song, 1989: 44 (redescription); Crosskey and Howard, 2004: 71 (checklist); Kim, 2013: 99 (Korean list and taxonomic notes); Adler and Crosskey, 2015: 101 (checklist).

*Simulium nipponense*: Shiraki, 1935: 59 (type locality: Japan).

*Simulium venustum*, not Say: Shiraki, 1935: 66 (redescription); Kono and Takahasi, 1940: 79 (taxonomy); Takahasi, 1950: 1559 (Japanese list).

*Simulium* (*Simulium*) *venustum*, not Say: Ogata and Sasa, 1954: 332 (Japanese list); 1955a: 10–18 (in Japanese key); Ogata et al., 1956: 91 (taxonomy and ecology); Anonymus, 1965: 192 (redescription in Japanese).





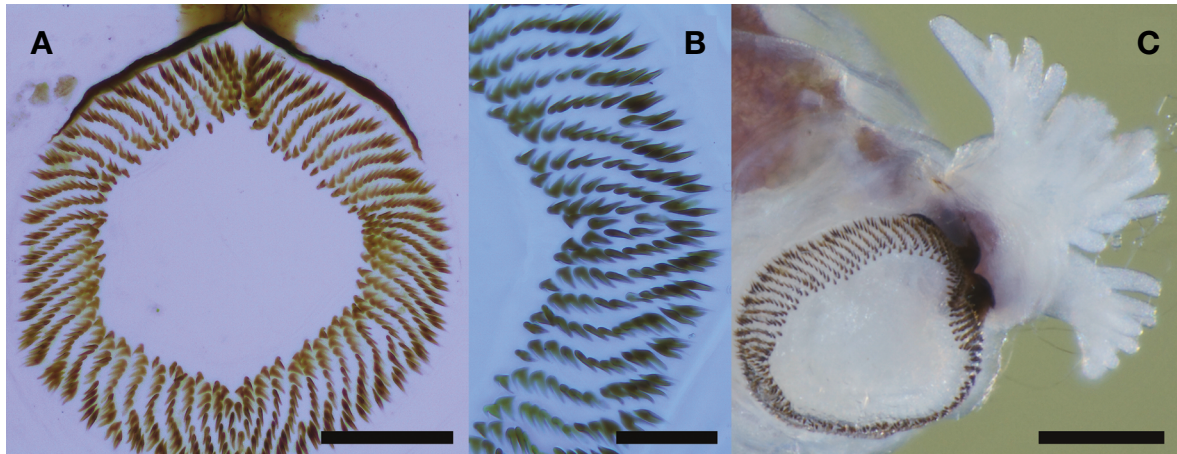
**Fig. 33.** *Simulium* (*Simulium*) *arakawae*. A, Larva, lateral view; B, Larval head, dorsal view; C, Larval head, ventral view; D, Larval head and gill histoblast, lateral view; E, Larval hypostoma, phase-contrast micrograph. Scale bars=1 mm (A), 0.5 mm (B–D), 50  $\mu$ m (E).

**Material examined.** Korea: Gangwon-do: Chuncheon-si, Seo-myeon, Geumsan-ri, 37°54'20"N, 127°41'05"E, 12 Nov 2009, Kim SK (10 ultimate/penultimate, 5 early instar larvae); Hongcheon-gun, Hongcheon-eup, Haoan-ri, 37°40'04"N, 127°50'44"E, 15 May 2010, Kim SK (3 ultimate instar larvae; 4 pupae); Hongcheon-gun, Seo-myeon, Eoyupo-ri, 37°42'57"N, 127°41'59"E, 10 Jun 2010, Kim SK (163 ultimate/penultimate, 37 early instar larvae; 54 pupae); Jeollanam-do: Sunchang-gun, Bokheung-myeon, Daebang-ri, Churyeongcheon stream, 35°25'14"N, 126°56'21"E, 2 Jun 2012, Kim SK (1 ultimate instar larva; 1 pupa); Gangwon-do: Wonju-si, Hojeo-myeon, Gosan-ri, 35°29'46"N, 127°55'49"E, 11 May 2013, Kim SK (10 ultimate/penultimate, 1

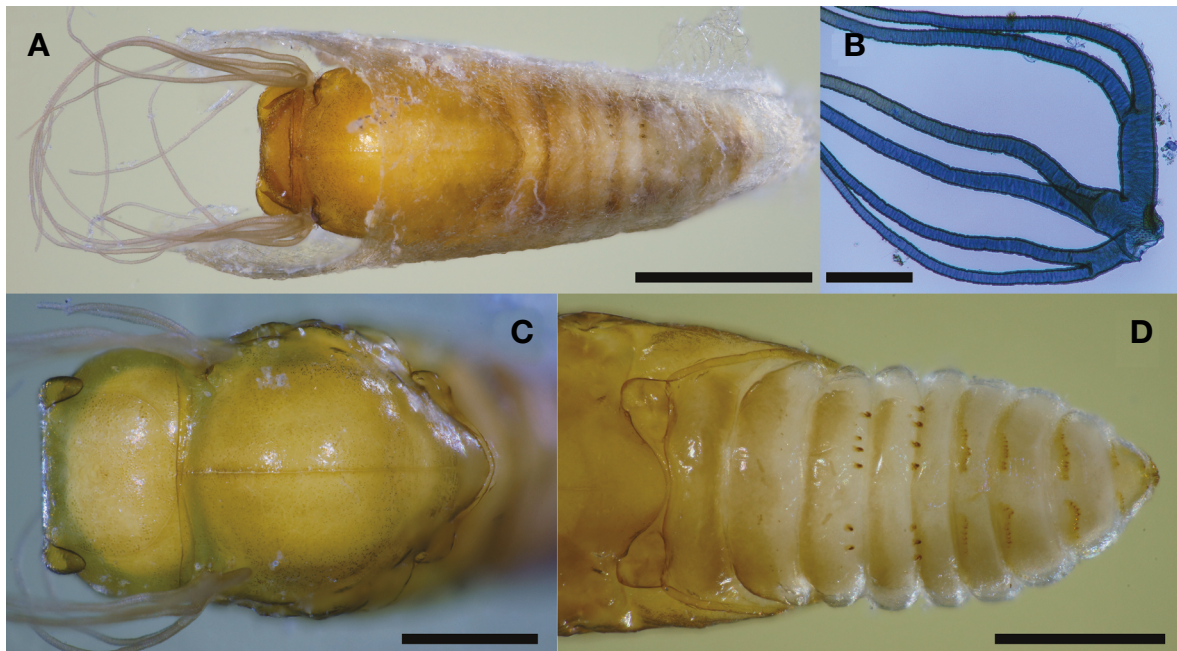
early instar larvae; 17 pupae).

**Diagnosis.** This species can be distinguished from other Korean black flies by the combination of the following characteristics: cocoon slipper shaped, gill of 6 filaments, widely divergent, stalk of dorsalmost pair directed upward, pupal abdominal tergite 6–9 with spine combs; and larvae with head spot negative, H-form, postgenal cleft round nose bullet shaped.

**Description.** Mature Larva (Fig. 33). Body length 5.7–6.7 mm ( $n = 10$ ). Body (Fig. 33A) greyish brown to reddish brown ground color. Head capsule (Fig. 33B–D) yellowish brown, mottled with dark spots; head spots negative, surrounding areas dark, making H-form. Antenna (Fig. 33B)



**Fig. 34.** *Simulium (Simulium) arakawae*. A, B, Hooks of posterior proleg, phase-contrast micrographs; C, Rectal papillae, postero-ventral view. Scale bars=0.1 mm (A), 50  $\mu$ m (B), 0.2 mm (C).



**Fig. 35.** *Simulium (Simulium) arakawae*. A, Pupa and cocoon, dorsal view; B, Gill filaments, phase-contrast micrograph; C, Pupal head and thorax, dorsal view; D, Pupal abdomen, dorsal view. Scale bars=1 mm (A), 0.2 mm (B), 0.5 mm (C, D).

yellowish brown, distal article brown, as long as labral fan stem. Labral fan (Fig. 33B, C) with 33–40 primary rays. Postgenal cleft (Fig. 33C) deep, round nose bullet shaped, not sharply pointed, about 1.2–1.4 $\times$  as long as wide, about 2–3.5 $\times$  as long as postgenal bridge; elongate lateral spot present, indistinct. Lateral surface of head capsule (Fig. 33D) without spot directly under ocelli, negative spots present near postoccipt. Gill histoblast with 6 filaments (Fig.

33D). Hypostoma (Fig. 33E) with 9 apical teeth; median tooth prominent, lateral teeth as long as median tooth; sub-lateral teeth near lateral teeth well developed; 1–2 paralateral teeth weakly developed; 4–5 lateral serrations well developed; hypostoma with 4 apically branched hypostomal setae. Posterior proleg (Fig. 34A, B) with 11–12 hooks in about 64–68 rows. Rectal papillae (Fig. 34C) of 3 lobes, each with 5–8 digit-like long secondary lobules.



Pupa (Fig. 35). Body length (excluding gill filaments) 2.7–3.2 mm (n = 10). Cocoon (Fig. 35A) slipper shaped, enclosing base of gill filaments, 3.7–4.3 mm long. Gill (Fig. 35B) with 6 filaments, 2 + 2 + 2 arrangement, stalk of dorsal pair longer than the others, directed upwardly. Cephalic plates and thorax (Fig. 35C) moderate to densely covered with small tubercles. Frons with 2 short, simple trichomes; face with 1 short, simple trichome. Thoracic trichomes in 6 pairs, short and simple, about 1.4 × as long as cephalic trichomes. Abdomen (Fig. 35D) with each side of abdominal tergites III and VI with 4 anteriorly directed spine hooks on posterior margin; segment V without spines; segments VI–IX with row of small spine combs; terminal hooks moderately developed.

**Distribution.** Korea, China, Japan.

**Remarks.** Erroneous publication date for this species was originally given by Kono and Takahasi (1940) who established *arakawae* as a new synonym of *venustum* Say and gave its original reference as “Dai Nippon Gaichu Zensho, II, p. 85 (1921)”. After that all subsequent publication cited original date for Matsumura as 1921, which is third edition of Matsumura’s work (Takahasi, 1995). All Japanese “*venustum*” are misidentification of *Simulium* (*Simulium*) *arakawae*. The larvae and pupae of this species were primarily collected from low land streams with moderate flow and high organic matter content, adhering to rocks and trailing grasses, leaves and twigs. The larvae and pupae were collected along with as many as 8 other black flies.

## ACKNOWLEDGMENTS

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